Things and Patterns – from Pyramiden to Patagonia

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Birgitte Skar, Heidi Breivik og Martin Callanan (red.)

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Innhold

Tema 1 Tidlig forhistorisk tid; stein, bilder og landskap

Tema 2 Komparative og globale perspektiver på menneskers relasjon til havet

Tema 3 Samtidsarkeologi og arkeologi i hverdagen, arkeologiens hverdag

Tema 4 Vitenskap, ord og bilder – visual essays

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Late Pleistocene Archaeology and Palaeoecology of Relict Raised Marine Landforms on Quadra Island, West Coast of Canada

Daryl Fedje, Christopher F.G. Hebda, Duncan McLaren

ABSTRACT

The Assu Palaeo-Tombolo (EbSh-116) and Assu 195 m Terrace (EbSh-117) archaeological sites on Quadra Island, off the west coast of Canada are associated with ancient marine landforms now stranded at 150 m and 195 m above modern sea level. These sites may date to between c. 13,800 and 14,200 years ago based upon new radiocarbon dates and correlation with a previously established Quadra Island relative sea level history. Both sites are located on what were then highly protected shorelines with easy access to intertidal and nearshore resources and are directly adjacent to small creeks which could have provided fresh water. By c. 14,200–14,000 years ago, the local vegetation was likely dominated by open pine forest with possible food and medicinal plants available nearby. As relative sea level dropped below the elevation of the palaeomarine landforms and forests began to thicken in the latest Pleistocene, these locations would have become less attractive to early people and may have been abandoned in favour of sites closer to the regressing shoreline.

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We acknowledge that our study area is comprised of lands that are within the territories of the We Wai Kai, We Wai Kum, K'omoks, Xwemalhkwu and Klahoose Nations. We are grateful for the permissions and support that have been given for our research. We appreciatively acknowledge the support of Eric Peterson and Christina Munck, Hakai Institute and Tula Foundation staff and our amazing crew. Field crew included McIntyre Barrera, Jenny Cohen, Angela Dyck, Daryl Fedje, Chris Hebda, Al Mackie, Quentin Mackie, Duncan McLaren, Joanne McSporran, Chris Roberts, Linda Rutledge and Nicole Smith. Figures were drafted with the assistance of Keith Holmes and Nicholas Hebda.

Introduction

In this chapter we briefly describe investigations at two archaeological sites, the Assu 195 m Terrace site (EbSh-117) and the Assu Palaeo-Tombolo site (EbSh-116), near Assu Lake on Quadra Island, off the west coast of Canada (Fig. 1). This area was initially investigated as part of the Discovery Islands Landscape Archaeology (DILA) project, from 2014–2017, which aimed to better understand the early archaeological and ecological history of the Discovery Islands (Fedje et al. 2021a). Additional investigations were conducted in 2022 and 2024 as part of the Northern Vancouver Island Archaeology and Paleoecology Project (McLaren and Dyck 2026). Both projects focused on the terminal Pleistocene (~15,000 to 11,700 years ago). Archaeological sites dating to this time do occur in the region but are relatively rare (e.g. McLaren et al. 2018, 2025, Gauvreau et al. 2023, Waters et al. 2011, Kenady et al. 2011). This is at least partly due to the dynamism of the early post-glacial coastal landscape where relative sea level, climate, and ecology were changing rapidly (McLaren et al. 2020). To locate archaeological sites from these early times we first investigated the local environmental history, especially relative sea level change, as people would have been most active on the shorelines that have shifted over the millennia. Sites located along present day and relict ocean shorelines of Quadra Island have yielded radiocarbon dates between recent times and 12,800 years ago and sea level correlation dates (cf. Breivik 2014) as early as c. 14,200 years ago (Fedje et al. 2021a, b, McLaren and Dyck 2026: this chapter).

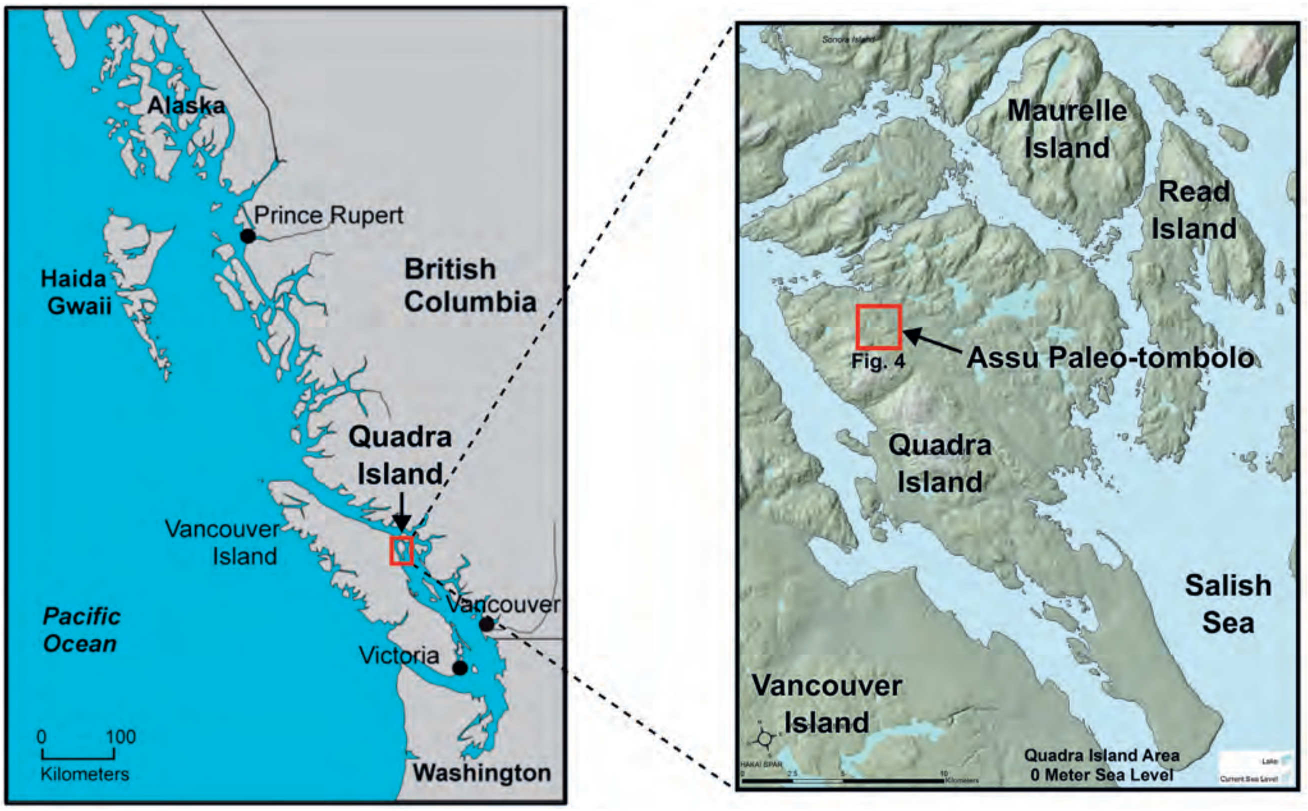

Figure 1. Quadra Island study area in coastal British Columbia, Canada.

Sea level and palaeolandscapes

The sea level history for the Quadra–Discovery Islands study area was refined during the DILA archaeological and palaeoecological investigations (Fig. 2, Fedje et al. 2018, 2021b) from the work of James et al. (2005). Samples were collected from sediment cores and stratigraphic sections at elevations from c. -1 m to +195 m above modern sea level (asl).

The elevation and timing of the post-glacial marine limit in the Quadra Island area are not certain. However, LiDAR modelling suggests that marine terrace formation extends to c. 205 m asl (see Fig. 5 below). LiDAR, also called airborne laser scanning, is a remote sensing method where ground laser points are collected from an aircraft and used to generate high-resolution digital elevation models of the terrain features below the tree canopy. Our palaeoecological investigations show that relative sea level (RSL) was 200 m asl c. 14,300 years ago, fell rapidly to c. 1 m asl by 12,000 years ago, rose to c. 3 m asl 11,300 years ago, and then fell gradually to near the modern level by 2,000 years ago. Well-defined palaeomarine features such as raised beaches, tombolos, spits and deltas (Fedje et al. 2018, 2021b, Lausanne et al. 2019) suggest sea level change was, at least in part, episodic. This may reflect occasional rapid tectonic adjustments (Mathewes and Clague 1994) as well as post-glacial isostatic and eustatic changes resulting from regional and global climate change (Friele and Clague 2002, Clague and James 2002, Khanna et al. 2017). Discernable marine terraces at ca. 3 m, 12 m, 28 m, 75 m, 150 m and 195 m asl support the premise that sea level stillstands or slowstands occurred during RSL regression (Fedje et al. 2021b). We focussed on these marine terraces, as the stillstands would have provided time to build up a more substantial archaeological material record, as opposed to one that is very thinly spread during periods of rapid marine regression (c. 10 cm per year between 14,000 and 12,000 years ago).

Quadra Island was significantly smaller prior to 13,000 years ago, and most of the eastern coastline was much more exposed than today, with a wind and wave fetch of more than 70 km to the southeast on the east side of the island (Fig. 3).

Prior raised beach archaeological investigation on Quadra Island

During the 2014–2017 DILA project, 48 archaeological sites on raised beach landforms were located, primarily through a LiDAR-based predictive modelling survey of c. 4 m, 10 m and 30 m asl marine shoreline

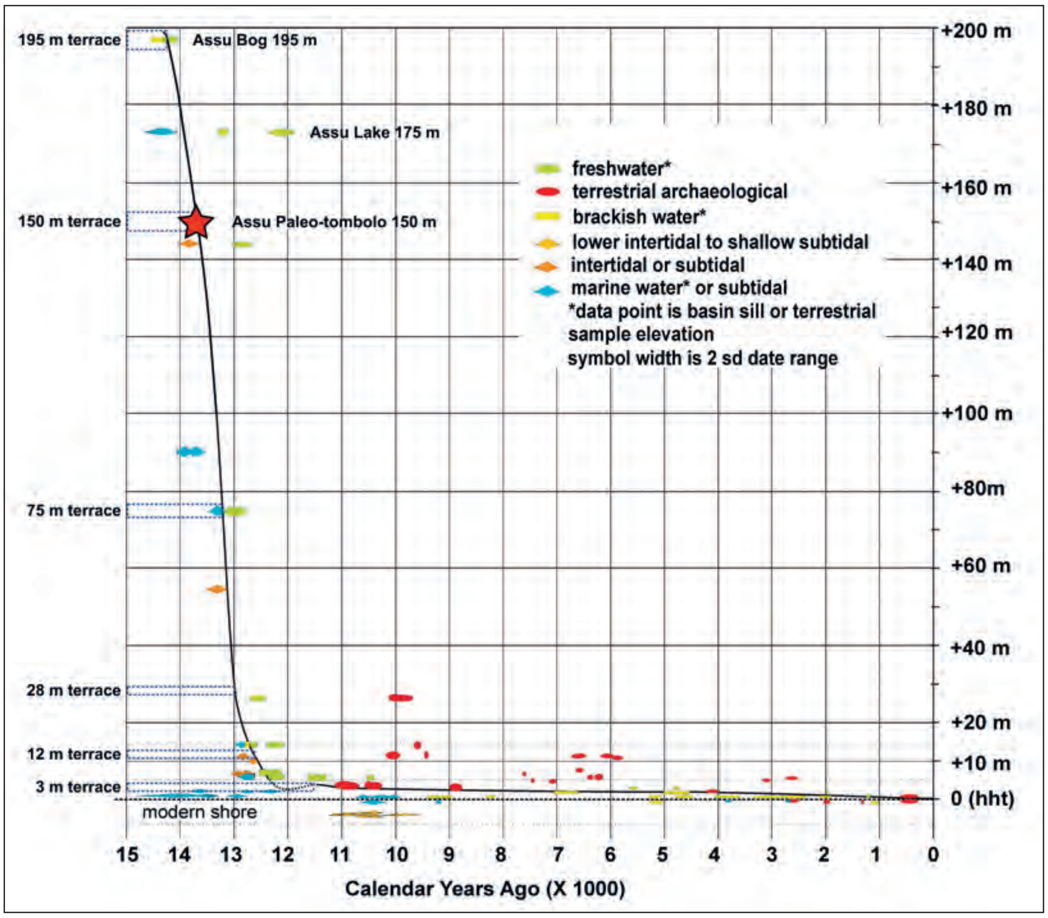

Figure 2. Quadra Island sea level history (adapted from Fedje et al. 2018). Sea level regressed from Assu Bog (195 m) and Assu Lake (175 m) at c. 14,200 and 14,000 years ago respectively (Fig. 4).

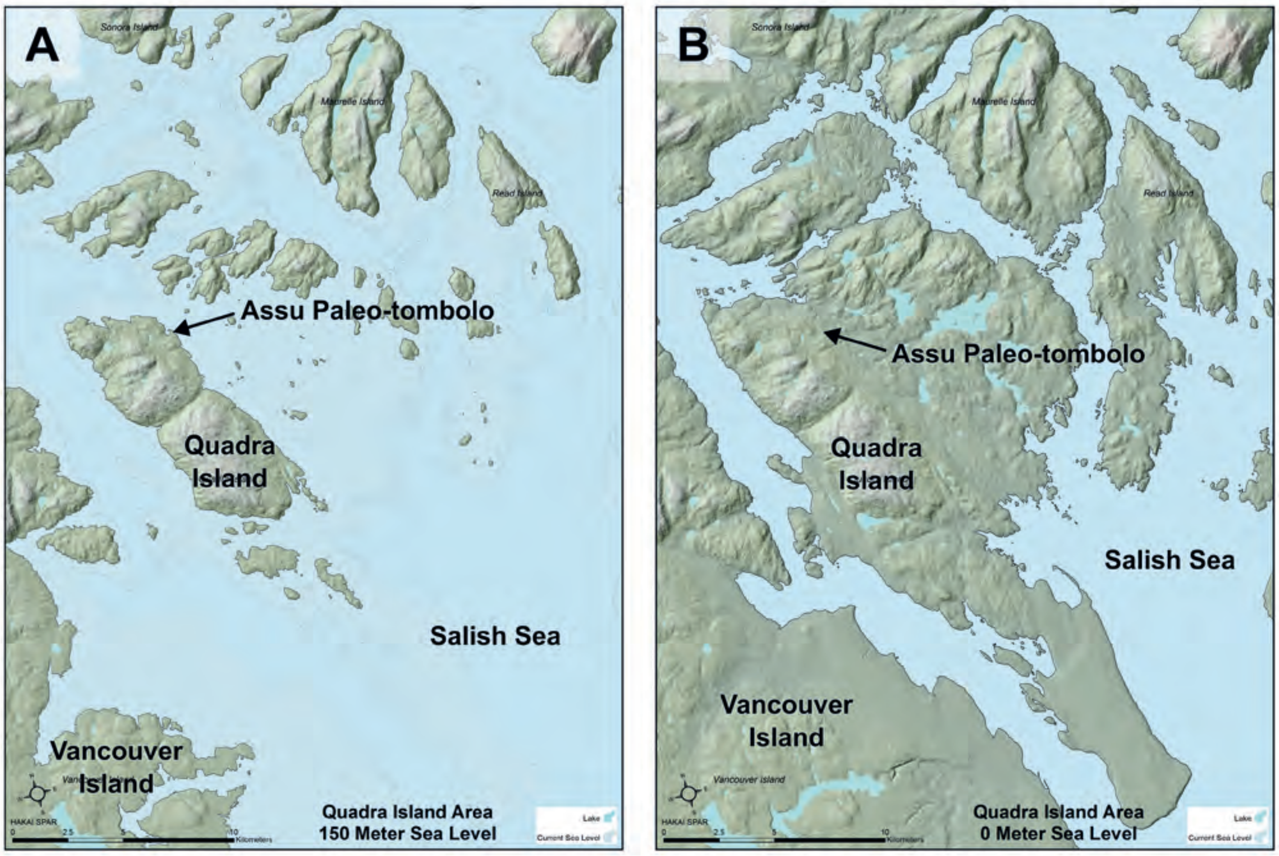

Figure 3. Discovery Islands landscape at (a) c. 13,800 years ago (150 m asl) and (b) c. 12,000 years ago and modern (0 m asl). Maps prepared by Keith Holmes.

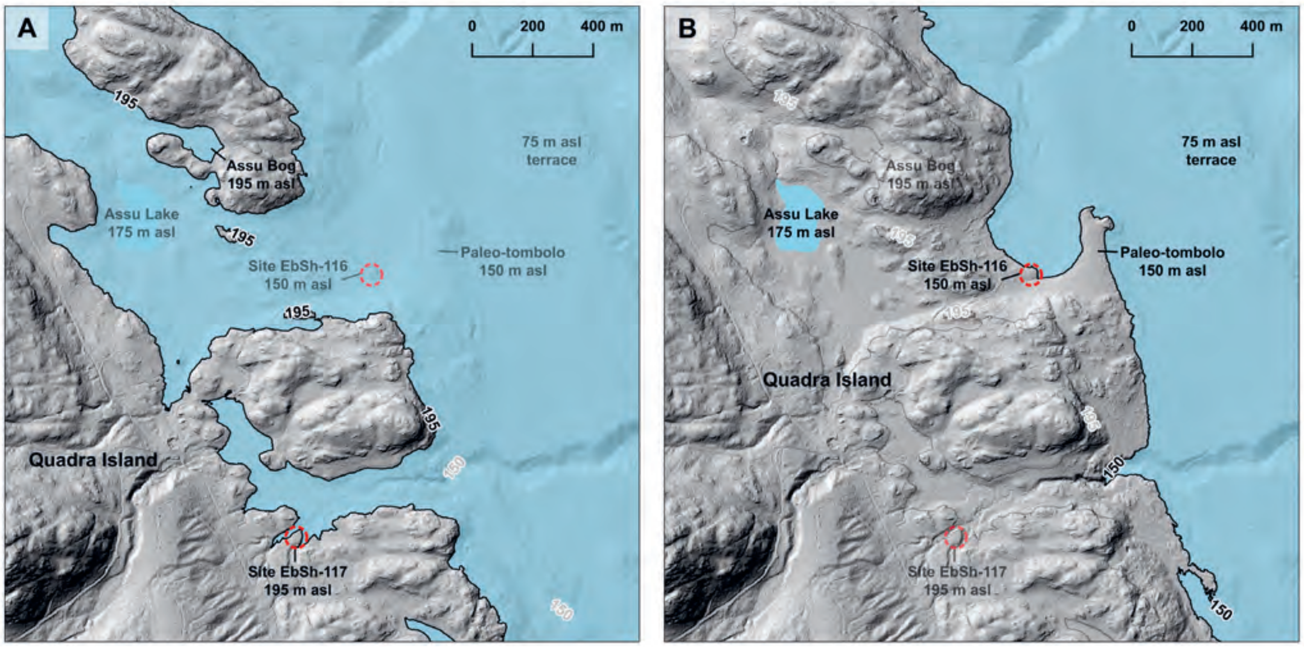

Figure 4. LiDAR image flood models showing Assu Lake environs study area and archaeological sites at 195 m asl (~14,200 years ago, panel A) and 150 m asl (~13,800 years ago, panel B).

geomorphic features (Vogelaar 2017, Fedje et al. 2021a, b, Lausanne 2018, Lausanne et al. 2019). Several of the terraces and sites thereon were dated based on radiocarbon dating and the region's relative sea level history (Fedje et al. 2018, 2021a, b; cf. Breivik 2014, Svendsen and Mangerud 1987). The c. 3-4 m asl terrace (an apparent stillstand and minor transgression) dates from at least c. 11,000–10,400 years ago based on several radiocarbon assays. The c. 10 m asl terrace has been radiocarbon dated to between c. 12,800 and 12,700 years ago. The 30 m asl terrace dates to c. 13,000–12,900 years ago based on sea level history (Fedje et al. 2018). Higher elevation marine terraces, at 150 m and 195 m, were observed from a LiDAR derived bare earth model collected by the Hakai Institute in 2017 but were only briefly investigated at that time (McLaren and Dyck 2026). The date of occupation for any sites associated with these high marine terraces could potentially be inferred from their fit to the Quadra Island sea level curve (Fedje et al. 2021b), on the assumption that people would have been drawn to the regressing shoreline by intertidal and marine resources.

Recent archaeological reconnaissance

Two archaeological sites, the Assu 195 m Terrace site (EbSh-117) and the Assu Palaeo-Tombolo site (EbSh-116) are described here. These sites are associated with relatively high elevation ancient marine landforms (Fig. 4).

Assu 195 m Terrace Site (EbSh-117)

In 2017, a brief archaeological survey was conducted on raised marine landforms at c. 190–200 m asl observed when conducting sea level studies in the Assu

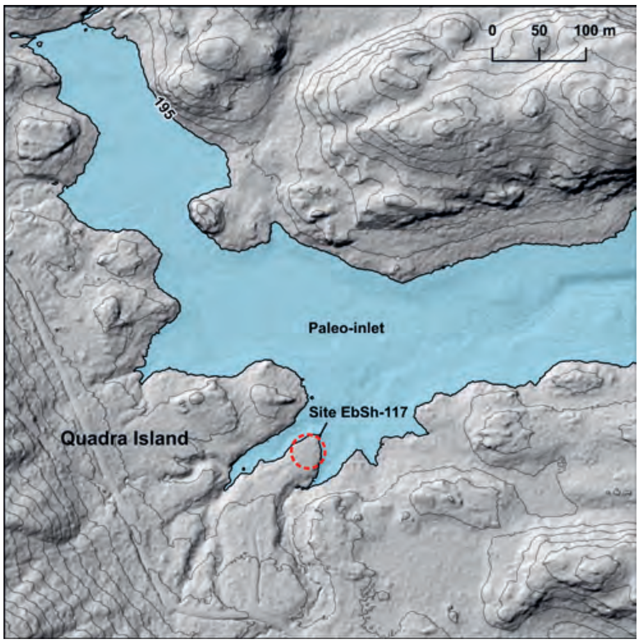

Figure 5. LiDAR image flood model showing location of the Assu 195 m Terrace site (EbSh-117) and associated geological features. Contour interval 5 m.

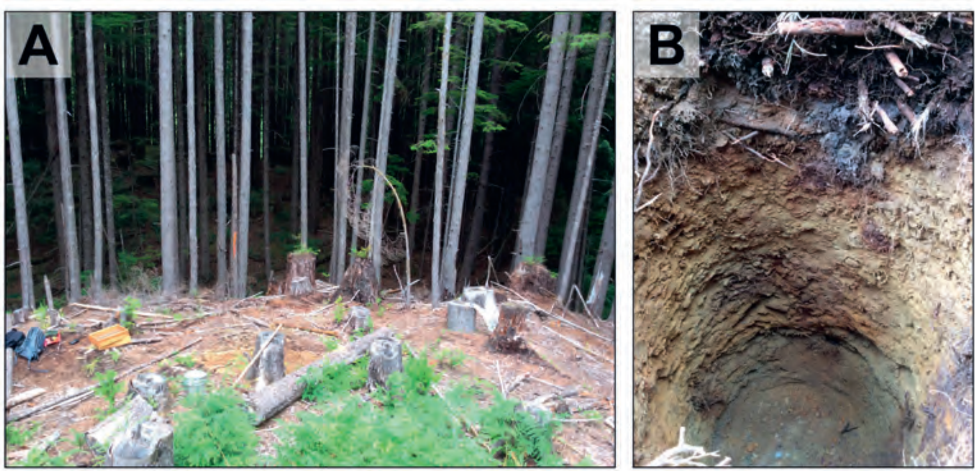

Figure 6. a) 195 m terrace promontory; b) shovel test DC with duric pea gravel exposed at base.

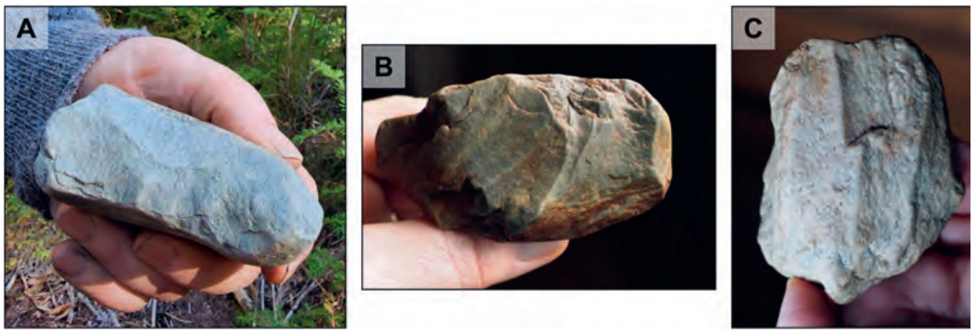

Figure 7. Select lithic artifacts from Assu 195 m Terrace (EbSh-117) site: a, b) scraper planes, c) waterworn blade core. Photos: a) Duncan McLaren, b) and c) Joanne McSporran.

Lake area (prior to obtaining LiDAR imagery). This work entailed shovel testing and the examination of areas with exposed mineral soil. A small number of artefacts, mostly waterworn, were observed in association with a well-defined palaeomarine terrace feature at 195 m asl (Figs 4–7). The lithic artefacts included flakes, scraper planes, a blade core and a small discoidal core. The artefacts were manufactured from chert and fine-grained quartzite. Revisiting the area in 2022, we recovered additional archaeological material (McLaren and Dyck 2026). One artefact (Fig. 7c) was found on the surface of the terrace edge while the remainder (e.g. Figs 7 a-b) were surface finds from the creek edge at the base of the c. 3 m-high terrace.

No archaeological material was recovered from shovel tests excavated near the terrace edge. The tests bottomed out on a strongly cemented sandy pea gravel (Fig. 6). Excavation of larger test units and the use of tools that can penetrate these duric sediments (cf. Yeatman Bay site excavations – Fedje et al. 2021a, b; McKeague and Sprout 1975) would be needed to locate any *in situ* archaeological deposits they may contain. Surface context of the lithic assemblage and an absence of *in situ* organic remains prevents the Assu 195 m Terrace site from being securely dated. However, the location at the edge of a palaeomarine terrace and waterworn character of some of the artefacts suggests association with the marine shoreline. If so, correlation with the Quadra Island sea level history (Fedje et al. 2018, 2021b) would suggest an age of c. 14,200 to 14,100 years ago.

Detailed palaeoecological reconstruction was not carried out for this site, but LiDAR data and the analyses of core samples from nearby Assu Bog (Fedje et al. 2018, 2021b) and the Assu palaeo-lagoon, described in detail below, suggest a similar sea level regression and palaeoecological history (Figs 2, 4, 5).

Test DC Stratigraphy

Depth (cm)	Sediment
0–20	Humic layer
20–60	Red-brown silty sand
60–70	Grey sand
70–72	Strongly cemented (duric) orange-brown sand
72–75	Strongly cemented grey sand with some rounded pea gravel
75+	Strongly cemented grey sand with pea gravel (too concreted for shovel and trowel excavation)

Assu Palaeo-Tombolo Site (EbSh-116)

In 2022 and 2024, brief archaeological surveys were conducted was conducted on a raised marine landscape identified from LiDAR imagery obtained during the DILA project (Figs 4, 8). The 2022 survey focused on a palaeo-tombolo and regressing spit around an ancient lagoon. The palaeo-lagoon (now a wetland) is 143 m asl and the upper surface of the tombolo is 150 m asl. The archaeological work entailed shovel testing and examining areas of exposed mineral soil.

The upper part of the tombolo exhibits a thin (5–10 cm thick) pebbly gravel surface layer, likely a lag formed during marine regression as strong winds entrained the finer sandy sediments, possibly blowing them into the deeper part of the adjacent basin. The lag overlies massive (> 2 m thick) gravel-rich coarse sand with occasional rounded to sub-rounded clasts to pebble size on the palaeo-lagoon side of the tombolo (Fig. 9) and coarser gravel and pebble-rich sediment with rounded clasts to boulder size on the formerly highly exposed outer side. The tombolo area was almost entirely logged in 2023, leaving a dense layer of woody debris on the surface. There were, however, a few small patches of mineral sediment exposure in the area and a few lithic artefacts were observed on the lag surface. An intensive shovel test programme would be needed to determine the presence/location of any *in situ* archaeological remains on or immediately above the tombolo proper.

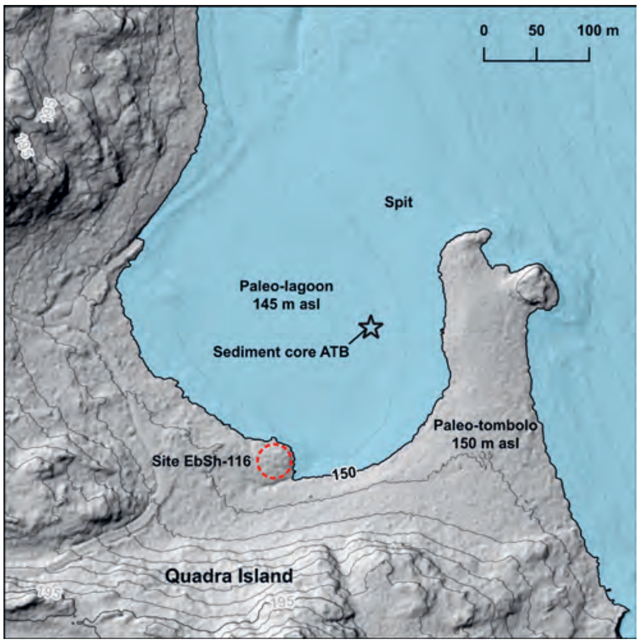

Figure 8. LiDAR image flood model showing location of Assu Palaeo-Tombolo site (EbSh-116) and associated geological features. Contour interval 5 m.

Figure 9. Photo of road cut into palaeo-tombolo. Scale bar 1 m.

Lithic artefacts were more abundant, though still relatively scarce, in the area of a 150 m asl bedrock-constrained promontory adjacent to a small stream that feeds into the west side of the palaeo-lagoon from Assu Lake. The artefacts were recovered from test excavations and from sediment exposed by windthrown trees.

In 2022, a total of fifteen 0.5 m^2 shovel tests were excavated along the tombolo and adjacent bedrock bench. Three of the tests on the bedrock promontory produced stone tools. In addition, a small number of surface finds of lithic artefacts were collected from exposures at the base of windthrown trees in the same area.

In 2024, a 0.7 m^2 unit (QD3) was excavated adjacent to a 0.5 m^2 test (QD2, Fig. 10) that produced artefacts in 2022 in order to recover dateable organics in good archaeological context. Although most of the palaeo-tombolo area and the south side of the promontory had been heavily disturbed by logging within the past year, part of the bedrock promontory with previously artefact-bearing shovel tests was outside the logged area. The 2024 unit was positioned in a 70 cm-deep sediment filled depression that had trapped sediment within an area of glacially-grooved bedrock. The glacial grooves run parallel to the front of the promontory, facing the palaeo-lagoon. Moss-covered striae ridges which have less than 10 cm of humic material and little or no mineral sediment are clearly visible between the grooves for at least 10 m, running in a northwest to southeast orientation.

A few lithic artefacts were recovered in the unlogged area, both from the excavation unit and from surface exposures of mineral sediment. Artefact recovery was limited to a small number of chemically weathered andesite lithic flakes, flake tools, cores and core tools (Fig. 11).

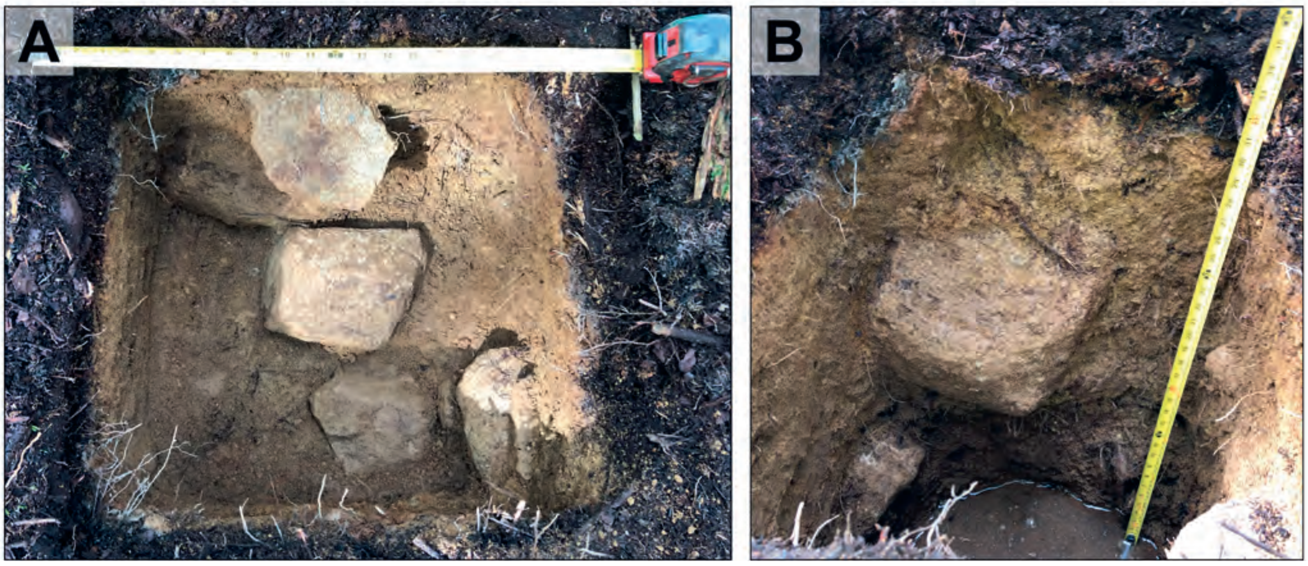

Figure 10. Test excavation QD2 at Site EbSh-116. Plan view at 50 cm (a) and oblique view of profile at 95 cm depth (b).

Test QD2 Stratigraphy

Depth (cm)	**Sediment**
0–15	Humic layer
15–20	Bf red-brown gravelly sand with few clasts to cobble size
20–25	Yellow-brown silty sand with pea gravel
25–35	Yellow-brown sandy silt
35–70	Yellow-brown sandy silt with small amounts of pea gravel
70–95	Dark red-brown hardpan (duric) sand with dense roots and gravel
95–100	Green-grey clayey silt

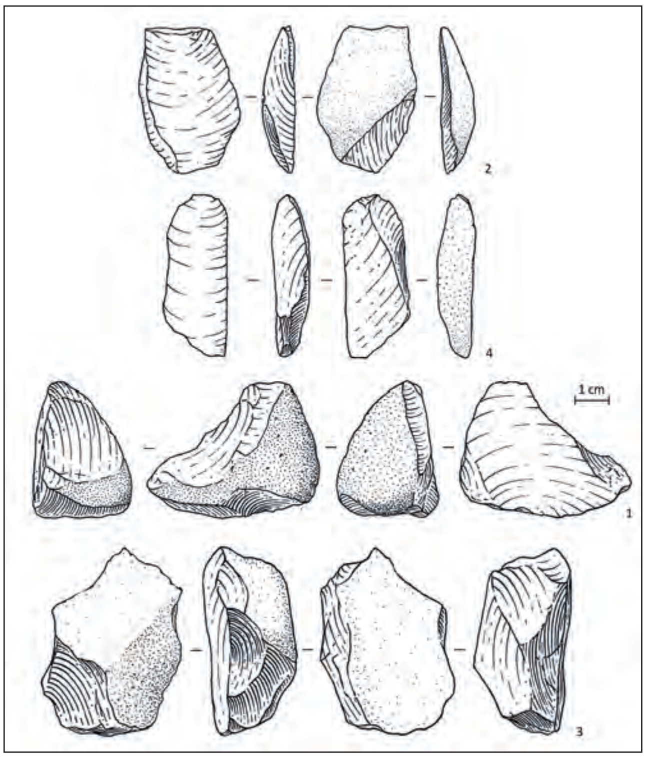

Figure 11. Select stone tools (1) pebble notch/scraper from Test DA1; (2) flake from Test CCL1; (3, 4) scraper plane and flake from Test QD2. Illustrated by Vanya Law.

Chronology

Although charcoal was observed during archaeological testing, none was collected due to evidence of extensive recent forest fire activity with root burns extending to the base of the test units from which archaeological material was recovered. Determining the age of the site is therefore limited to referring to the local sea level history. To better constrain relative sea level history in the adjacent basin (and therefore the inferred age of human occupation on the promontory) a Livingstone corer was used to obtain sediment from which to identify and date the transition from marine lagoon to pond/bog in the palaeo-lagoon (Assu Tombolo Bog [ATB, informal name], Figs 8, 12). Based on association with the Quadra Island sea level curve (Fedje et al. 2018, 2021b), the site was thought to date to c. 13,800 years ago. Dating results from the sediment core collected in 2024 (Table I, Fig. 13) suggest an age of c. 14,000 to 13,700 years ago for the formation of the palaeo-lagoon.

Table I. Radiocarbon assays on samples from Assu Tombolo Bog core (ATB1). Three samples (UCIAMS-306649, UCIAMS-306648, UCIAMS-299200) have been calibrated using the mixed marine and terrestrial curve in Calib 8.2 (Reimer et al. 2020) with an 86% contribution of marine carbon. The percentage of marine carbon for all three of these assays was calculated using the $\delta^{13}C$ of UCIAMS-306649 (-15.6‰) relative to a fully terrestrial sample (-21.0‰) versus a fully marine sample (-14.5‰) as per Fedje et al. (2021c). The marine contribution was calculated using a ΔR-weighted mean of 576 years following Schmuck et al. (2021).

Site (Core)	Depth (cm)	Dated Material	Lab Number	^{14}C Age BP	±	δ13C	Cal BP Median	Cal BP Range (2σ)
ATB1	153-156	Conifer cone scale	UCIAMS-306647	12130	260		14,159	15,034-13,495
ATB1	158	*Potamogeton* seed	UCIAMS-306649	12935	30	-15.6	13,910	14,059-13,762
ATB1	158-159.5	*Potamogeton* seed	UCIAMS-306648	12895	35	*	13,869	14,040-13,701
ATB1	159-159.5	cf. *Carex* seed	UCIAMS-299200	12750	130	*	13,704	14,227-13,224

Figure 12. Basal section of 1.6 m sediment core recovered from Assu Tombolo Bog (ATB).

Palaeoenvironment

Diatom and pollen and spore assemblages from the Assu Tombolo Bog core were used to reconstruct the late Pleistocene landscape around site EbSh-116 (Fig. 13 and Tables AI and AII). Diatom species reflect water chemistry and provide a proxy for marine transgression and regression events (Zong and Sawai 2015), while pollen and spores provide a representation of both regional and local vegetation composition at the time they were deposited (Hebda 1981).

Diatoms were concentrated through a settling process which removed coarse sediment and were plated onto microscope slides using Norland Optical Adhesive #61 (Battarbee et al. 2002, Fedje et al. 2018), then assessed for diagnostic taxa to determine basin salinity. Slides were analysed using a Zeiss Axio Scope.A1 microscope with differential interference contrast, with a minimum of 150 diatoms counted at 1000x magnification. Observed diatom floras were compared to those identified in Campeau et al. (1999), Cumming et al. (1995), Falu et al. (2000), Foged (1981), Hein (1990), Kelly et al. (2005), Pienitz et al. (2003), Spaulding et al. (2021), and Witkowski et al. (2000). Following Hustedt (1953), diatoms were assigned to five salinity classes: 1 – halophobian (freshwater, salt intolerant), 2 – oligohalobous indifferent (freshwater), 3 – oligohalobous halophilous (freshwater species tolerant of salinity up to 0.2 ppt), 4 – mesohalobous (brackish water species with optimal salinity in the range 0.2–30 ppt) and 5 – polyhalobous (marine water species with optimal salinity greater than 30 ppt). The salinity tolerance of identified flora was determined using the diatom flora references above and data from Denys (1992), Guiry and Guiry (2017), Hustedt (1953), Marohasy and Abbot (2007), Wilson et al. (1996) and Zong and Sawai (2015). Differential preservation is evident among the samples, with specimens in the lowest freshwater assemblages limited to highly silicified species.

Pollen and spores were prepared using standard methods (Faegri and Iversen 1989, Moore et al. 1995) including the addition of *Lycopodium* spores (University of Lund, Department of Geology Batch no. 100320 201, 14285 ± 501 *Lycopodium* spores/tablet) to determine pollen concentrations, treatment with KOH, HCl, and acetolysis. Samples were mounted on slides using glycerine jelly and analysed using either a Zeiss Axio Scope.A1 or a AmScope T690C-10MA compound light microscope at 400x or 600x magnification. A minimum of 480 pollen grains or spores were counted per sample. Pollen and spore identifications were carried out to the highest taxonomic resolution possible, relying on references including Demske et al. (2014), Hebda et al. (2002), Kapp et al. (2000), Martin and Harvey (2017), and PalDat (2000). Botanical nomenclature follows Klinkenberg (2020), and a list of scientific and common names is presented in Table AIII.

Results

Diatom assemblages from the four sand-rich basal samples (160–150 cm depth) suggest a slightly brackish freshwater pond environment with at least intermittent input of more strongly brackish water. The presence of *Diploneis interrupta* and *Planothidium delicatulum* in the lowermost samples indicates the basin was then at or immediately adjacent to a low-energy marine shore as these taxa are aerophyllic (intertidal salt marsh – cf. Watermann et al. 2004). These species may have been introduced to the basin from the beach during large spring tide or storm surge events. The overwhelming abundance of several Fragilariaceae species (especially *Pseudostaurosira*, *Staurosira* and *Staurosirella*) is consistent with cool, alkaline freshwater conditions immediately following marine regression from the basin (Witkowski et al. 1996, Pienitz et al. 1991, Bahls 2021).

The associated basal pollen zone, ATB-1 (160–143 cm), is dominated by *Pinus* with low levels of *Alnus* (both *A. rubra* and *A. viridis* types), *Tsuga mertensiana*, and *Populus*, as well as shrubs including *Salix* and *Shepherdia* and herbs including Poaceae, Cyperaceae, and Apiaceae. Aquatic taxa such as *Potamogeton* in the upper part of the zone and colonial green algae including *Pediastrum* and *Botryococcus* throughout suggest that the basin held standing fresh to fresh-brackish water. Trace amounts of *Sphagnum* may suggest its incipient growth along the margins. Pollen concentrations in zone ATB-1 begin at moderate levels in the lower organic silty sand (160–158 cm depth), then decrease notably in the overlying coarse sand (158–151 cm) before increasing by an order of magnitude in the upper part of the zone as peat accumulated (151–143 cm).

The upper diatom assemblages (146–131 cm) are freshwater ones, including the uppermost sample in

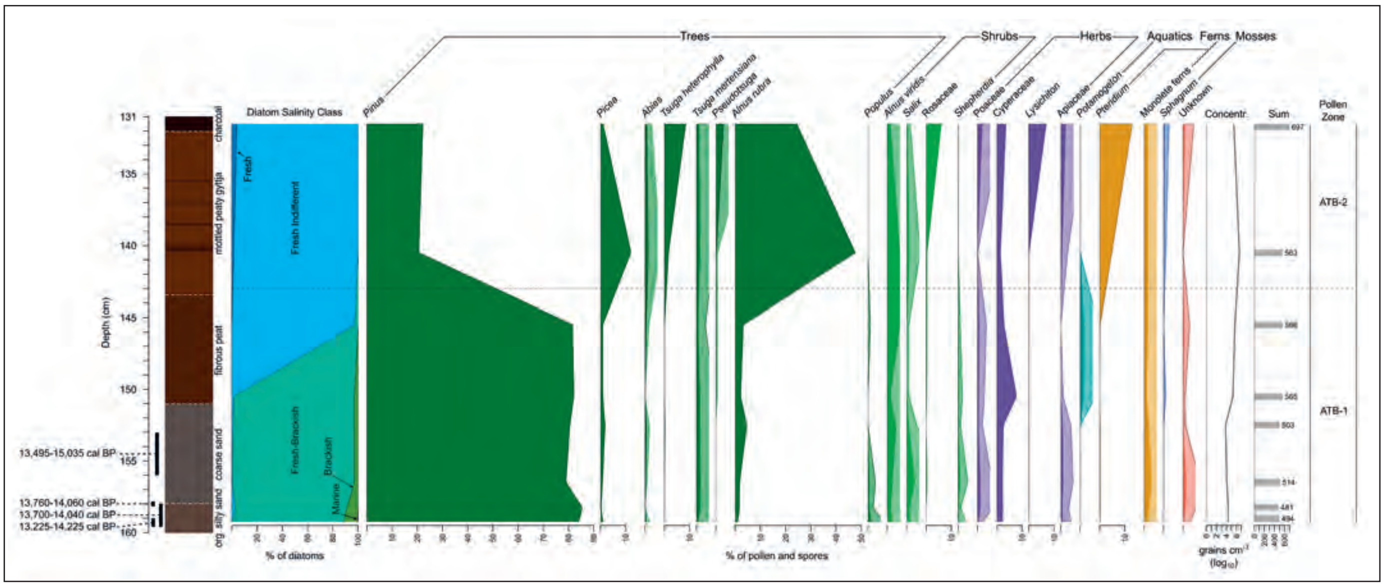

Figure 13. Percentages of selected diatom halobian classes (Hustedt 1953) and pollen and spore taxa from Assu Tombolo Bog (ATB) plotted by core depth (cm) using a custom script for the 'strat.plot' function in the rioja package version 1.0-6 for R x64 version 4.4.1 (R Core Team 2024). A 5x exaggeration has been applied to selected less frequent pollen and spore taxa to show their presence/variability with depth. Calibrated radiocarbon age ranges are plotted by depth to the left of the core stratigraphy. Pollen concentration, pollen sum, and pollen zones are depicted to the right.

pollen zone ATB-1 and all of ATB-2. Brackish and most fresh-brackish species disappear and are replaced by freshwater species dominated by *Aulacoseira* and *Pinnularia*.

The second pollen zone, ATB-2 (143–131 cm), is represented by two samples which demonstrate notable shifts in vegetation. The lower sample primarily contains *Alnus rubra* with moderate incidence of *Pinus*, *Picea*, and *A. viridis*, as well as small amounts of other conifers. Peripheral wetland taxa including *Salix*, Cyperaceae, and Apiaceae persisted along with increasing *Pteridium*, which may have occupied both the wetland edge and the forest understory. The upper sample in zone ATB-2 was collected from a 1 cm-thick charcoal layer, and the slide contained abundant charcoal fragments of varying sizes from both arboreal and herbaceous taxa. *A. rubra* and *Pinus* remained major constituents of the assemblage, but this was accompanied by a notable decrease in *Picea* and increases in *Tsuga heterophylla*, *Pseudotsuga*, *Pteridium*, and Rosaceae. Some wetland and lakeshore taxa increased including *Lysichiton*, Cyperaceae, *Poaceae*, and Apiaceae. Small but increasing amounts of *Sphagnum* and a reduction of *Potamogeton*, *Pediastrum*, and *Botryococcus* in ATB-2 may indicate the growth of peat mats around the basin and less standing water. Pollen concentrations continue increasing to a peak in the lower sample of zone ATB-2, before decreasing again somewhat in the upper sample of the zone.

Palaeo-Environmental Interpretation

Observations of a subsurface sediment lag on top of the tombolo and the well-sorted coarse sand in the ATB core suggest that in the early period following marine regression, freshly exposed mineral soil may have been removed from the top of the tombolo by the prevailing southeast winds and deposited in the adjacent protected basin. A possible local aeolian origin is corroborated by the pollen samples analysed from this upper sand deposit, which demonstrate the same assemblage as those above and below but with notably reduced pollen concentrations, indicating rapid sediment accumulation. Diatoms in the sediment suggest that the water in the basin was brackish to fresh-brackish during this pioneering interval. The windswept landscape was characterized by the dominance of shore pine, likely as a parkland or open forest under a cool and dry climate (see Hebda 1983, Lacourse and Mathewes 2005) with infrequent poplar or aspen interspersed and mountain hemlock on moist slopes or nearby uplands. Grasses, parsley family taxa, and shrubs like soapberry occupied clearings, while wetter sites and the margin of the palaeo-lagoon/lake were populated by sedges and willows. Radiocarbon dating of the ATB core and comparisons with regional records on Vancouver Island (e.g. Langley Lake and Enos Lake, Brown et al. 2022, Little Woss Lake, Hebda et al. 2022) suggest that the open pine-dominated ecosystem may have existed at the site from at least 14,000 years ago until ~13,500–13,000 years ago. As peat began to accumulate on top of the sand, the diatom assemblage changed rapidly to be characterized by freshwater taxa. However, the pine forest persisted, possibly reflecting a more rapid response by diatom populations in the basin than by the surrounding trees and plants with a much longer life cycle. Following the pine-dominated landscape, somewhat denser vegetation surrounded the basin with red alder stands along the lakeshore and spruce forest on the tombolo and adjacent uplands, possibly by ~12,500–12,000 years ago (cf. Brown et al. 2022, Hebda et al. 2022). Western hemlock and Douglas fir followed afterwards with increasing bracken fern under a drying and warming climate, aligning well with regional early Holocene assemblages (since ~11,000 years ago) (Brown and Hebda 2002, Brown et al. 2022, Hansen 1950, Lacourse et al. 2019, Lucas and Lacourse 2013).

Using radiocarbon dating of the ATB core and previous studies as chronological correlates, the promontory at EbSh-116 may have been suitable for a camp or a temporary refuge while plying the waters of the palaeo-Discovery Islands archipelago during and immediately following the interval of the sea level stillstand at ~150 m c. 13,800 years ago. Marine and littoral resources were likely widely available in the calm palaeo-lagoon or nearby, and food plants such as soapberries and possibly other berries (rose family taxa) as well as medicinal herbs (parsley family taxa) were likely accessible. The recovery of only a few simple stone tools, the site context, and age suggest it was a temporary camp. Conversely, significantly lower sea level (Fedje et al. 2018) combined with increased forest cover during zone ATB-2, and the development of wetland communities along the freshwater shoreline, indicate that the area of the tombolo was likely less attractive as a habitation site by ~13,000–12,500 years ago.

Discussion and Conclusions

As relative sea level dropped rapidly from its postglacial maximum in the Discovery Islands (Fedje et al. 2018), the interactions of isostatic rebound and global meltwater pulses likely resulted in brief intervals where the marine shoreline in the region was relatively stable, including at ~195 m asl around 14,200 years ago and at c. 150 m asl around 13,800 years ago (Fedje et al. 2021b, McLaren and Dyck 2026). These periods of a relatively stable shoreline were of sufficient duration, perhaps a few decades, to allow formation of the Assu 195 m asl Terrace and the 150 m Assu Palaeo-Tombolo and spit. During and immediately following these periods of relative stability, the landforms may have been attractive locations for human occupation. At these times, the sites were on a relatively small island (palaeo-Quadra Island, Fig. 3) in a highly exposed part of the Salish Sea. The Assu 195 m Terrace site would have been on the shore of a small, protected inlet c. 14,200 years ago (Figs 4, 5), and the Assu Palaeo-Tombolo site would have been sheltered by the adjacent tombolo (Figs 4, 8) c. 13,800 years ago. Both locations were well-protected from the open ocean and would have had ready access to intertidal and marine resources (Davis and Twidale 2011) as well as providing good access to open waters for travel.

The preliminary results from investigations at the Assu Palaeo-Tombolo site (EbSh-116) and Assu 195 m Terrace site (EbSh-117) provide optimism for future discoveries of human use of the early post-glacial landscape in the region. These data and the evidence for temporary stillstands or slowstands in the area (Fedje et al. 2021b) suggest that additional LiDAR modelling and surveys for terminal Pleistocene archaeological sites on marine proximal landforms could be productive.

Overall, archaeological evidence for early post-glacial human use of the coastal and coast-proximal landscape remains relatively limited for the environs of the Canadian west coast, especially for periods prior to 13,000 years ago. There is evidence of large mammal hunting c. 13,500 years ago in the Salish Sea area (Kenady et al. 2011, Waters et al. 2011); recent research at the Tsalwadi site on adjacent Vancouver Island (McLaren et al. 2025) has identified a stone tool-rich component dated to 14,100-13,300 years ago; and investigations at the Triquet Island and Pruth Bay sites on the central coast of BC have identified archaeological components dating to c. 13,900 and 13,100 years ago respectively (Gauvreau et al. 2023, McLaren et al. 2018). These studies, along with the preliminary work on Quadra Island reported here, provide a small window into early post-glacial human activity in this region. However, considerably more work will be needed to provide more robust evidence for early post-glacial occupations of the Discovery Islands.

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Appendix

Table AI. Diatom counts from Assu Tombolo Bog core (ATB).

Class	Species	131-132	140-141	145-146	150-150.5	156-157	158-158.5	159-159.5
1	*Frustulia saxonica*	5						
1	*Frustulia* sp.		2					
2	*Achnanthes minutissimum*				1			
2	*Aulacoseira* sp.	42	24					
2	*Brachysira brebissonii*	5						
2	*Cymbella ehrenbergii*			7			3	
2	*Diploneis finnica*			6				
2	*Encyonema minutum*	1						
2	*Encyonema nirvanic*	2						
2	*Eunotia faba*		1					
2	*Eunotia horstii*	2						
2	*Eunotia incisa*	5						
2	*Eunotia panda*	3						
2	*Eunotia pectinalis*	6						
2	*Eunotia* sp.	23	3					
2	*Gomphonema gracile*	1						
2	Gomphonema parvulum	5						
2	*Gomphonema sarcophagus*	1						
2	*Gomphonema truncatum*					1		1

Class	Species	131-132	140-141	145-146	150-150.5	156-157	158-158.5	159-159.5
2	*Lindavia praetermissa*		1					
2	*Lindavia radiosa*			4	1			
2	*Lindavia rossii*							
2	*Lindavia* sp.		28	58				
2	*Pinnularia brebissonii*	1	2					
2	*Pinnularia lata*	1						
2	*Pinnularia maior*	1		3				
2	*Pinnularia nodosa*		1					
2	*Pinnularia* sp.	3	24	24				
2	*Pinnularia subanglica*							
2	*Pinnularia subcapitata*	1	5					
2	*Pinnularia viridiformis*			2				
2	*Stauroneis* sp.	1	3	4				
2	*Tabellaria flocculosa*	15	17	5				
3	*Amphora libyca*						3	1
3	*Amphora pediculus*							4
3	*Cocconeis placentula*				3	6	5	4
3	Cymbella minuta					4		
3	*Cymbella muelleri*					5	1	
3	*Cymbella proxima*							4
3	*Encyonema silesiacum*						2	2
3	*Epithemia adnata*			2	7	9	5	17
3	*Epithemia argus*				2	4	5	15
3	*Fragilaria capucina*							2
3	*Frustulia vulgaris*				2			
3	*Gyrosigma acuminatum*				3	1		3
3	*Staurosirella martyi*				17	10	7	11
3	*Navicula aurora*					2	4	2
3	*Navicula oblonga*				2	2		2
3	*Nitzschia amphibia*							2
3	*Nitzschia sinuata*					3	2	
3	*Pseudostaurosira brevistrata*			1	17	99	62	74
3	*Pseudostaurosira parasitica*						1	
3	*Rhopalodia gibba*						1	1
3	*Staurosira construens*				63			
3	*Staurosirella leptostauron*				8	1		
3	*Ulnaria acus*					4	1	1
4	Diploneis interrupta						4	4
4	*Halamphora latecostata*							1

Class	Species	131-132	140-141	145-146	150-150.5	156-157	158-158.5	159-159.5
4	*Mastogloia taralunae*				2			
4	*Planothidium delicatulum*				2	2	3	10
4	*Surirella crumena*					3	3	3
5	*Rhopalodia pacifica*							1
	Total	124	111	116	130	156	112	165

Table AII. Pollen and spore counts from Assu Tombolo Bog core (ATB).

Taxon	131-132	140-141	145-146	150-150.5	152-153	156-157	158-158.5	159-159.5
Pinus	155	116	462	464	405	406	411	415
Picea	7	68	5	5	9	4	1	5
Abies	4	7	2		2	1		2
Tsuga heterophylla	59	9			1			
Tsuga mertensiana	8	8	4	8	7	8	7	5
Pseudotsuga	21	1	1	1				
Cupressaceae	2							
Arceuthobium	1	1						
Alnus rubra	170	268	18	12	23	9	8	5
Alnus viridis	8	28	28	6	17	10	6	9
Populus			1			3	2	6
Salix	2	6	1	1	4	17	5	8
Ericaceae	2							
Rosaceae	42	2	2	1		2		
Shepherdia			1	2	1	4	1	3
Poaceae	14		4	3	2	6	6	2
Cyperaceae	25	8	16	44	13	11	11	11
Asteraceae (*Asteroideae*)					1		1	
Artemisia				1		1		1
Ambrosia						1		
Ranunculus							3	
Brassicaceae				1				
Liliaceae					1			
Lysichiton	48							
Apiaceae				1	4	5	3	4
Heracleum (Apiaceae)	14	3						
Sanguisorba	1							1
Fabaceae								1
Potamogeton			8	7				
Menyanthes		1						

Taxon	131-132	140-141	145-146	150-150.5	152-153	156-157	158-158.5	159-159.5
Myriophyllum						1		
Lycopodium	1				1	1		2
Pteridium	90	27	1		1	1	1	1
Cryptogramma						1		
Trilete smooth	3							
Monolete fern verrucate				1	3	8	2	2
Monolete fern undiff.	11	9	9	5	7	7	8	8
Sphagnum	3	1		1				
Unknown	6		3	1	1	7	5	3
Exotic	32	2	16	40	1062	592	292	329
Total (-exotics)	697	563	566	565	503	514	481	494

Table AIII. Scientific and common names of plant taxa discussed in the text.

Scientific Name	Common Name
Pinus	pine
Picea	spruce
Abies	true fir
Tsuga heterophylla	western hemlock
Tsuga mertensiana	mountain hemlock
Pseudotsuga	Douglas fir
Alnus rubra	red alder
Alnus viridis	green alder
Populus	poplar or aspen
Salix	willow
Rosaceae	rose family
Shepherdia	soapberry
Poaceae	grasses
Cyperaceae	sedges
Lysichiton	skunk cabbage
Apiaceae	parsley family
Potamogeton	pondweed
Pteridium	bracken