

Sea Level Change and Archaeological Site Locations on the Dundas Island Archipelago
of North Coastal British Columbia

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DOCTOR OF PHILOSOPHY

In Interdisciplinary Studies

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Abstract

Coastal archaeological sites dating to the late Pleistocene and early Holocene are rare on the northwest coast of North America, as they are in many regions of the world, due to changing environmental factors, in particular glacial isostasy and eustasy, resulting in low visibility and survival of archaeological deposits. This dissertation outlines methods and results used to locate late Pleistocene and early Holocene archaeological sites on the Dundas Island Archipelago on the Northwest Coast culture area of British Columbia, Coast Tsimshian Territory, where archaeological sites older than 5,000 years BP are not known. Part of the reason for this is that masses of glacial ice accumulated on the Cordilleran Mountains of North America during the last glacial maximum, which depressed mainland coastal regions isostatically in relation to sea levels. As a result of lateral displacement of subcrustal material, areas to the west of the Cordillera bulged and landforms were raised relative to the sea. With deglaciation, the depressed crust began to rebound and the forebulge subsided resulting in rapidly dropping sea levels along the mainland to the east and rapidly rising sea levels along outer coastal islands to the west.

These processes occurred in concert with sea levels that began rising eustatically following the last glacial maximum. Between the inner and outer coasts lies the Dundas Island Archipelago. This research project hypothesized that the study area was close to a sea level hinge lying between these two regions with very different sea level histories. With less significant shoreline movement, it was further anticipated that shoreline situated archaeological sites dating to the late Pleistocene and early Holocene might be found in close proximity, although slightly higher than the present day shoreline. This dissertation addresses the following question: Where are late Pleistocene and early Holocene archaeological sites situated on the Dundas Island Archipelago? To address this question, this dissertation details the methods and results used to determine a sea-level and vegetation history for the Dundas Island Archipelago and the archaeological prospection that was undertaken along relict shorelines.

Pollen analysis of sediments from a lake core identified a sequence of six vegetation zones beginning before 12,385 BP. Based on diatom identification of cores from four lake basins, combined with supporting indicators, a sea level curve for the Dundas Islands was constructed showing a slow regression of shorelines from 13 m above the barnacle line to present day elevations over the last 12,000 years BP.

Drawing upon these palaeo-environmental data, areas were selected for archaeological survey and prospection. Field testing of these selected areas resulted in the identification of five archaeological sites dating to the early Holocene. These are the first archaeological sites dating older than 5,000 years BP that have been found and dated in Coast Tsimshian Territory. The elevations and radiocarbon dates on all archaeological

deposits are consistent with the sea level curve based on palaeo-environmental data points.

Overall, this dissertation draws upon palaeo-environmental methods and results for the purpose of identifying and interpreting archaeological sites situated on raised marine landforms.

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Dedication

For Oonagh Artemisia

Chapter I – Introduction

Stories, legends, and myths of floods form an integral part of the cultural traditions of near-shore peoples worldwide. Physical remnants of sea level changes are identifiable in topographic features and accumulated sediments in many coastal areas. A change of sea level may be a major event which can impress itself upon a population's social memory, in turn, making it an important and pivotal reference to local historical sequences. In such instances the topographic features and sedimentary evidence for such events can act as reminders and affirmations of events. This dissertation follows in this broad-based cultural tradition, as it is an attempt to tell a story of changing sea levels from physical remnants on the landscape. Here, the goal of telling a specific sea level history is archaeologically motivated and thus concerned, not only with the events surrounding changes in shoreline elevation, but also with the human reaction and adjustment to those events.

Changes in sea level have a tremendous impact on human settlement patterns along coastal and other water body margins: “tales of world-destroying floods are one of the most widespread and continuously evolving categories of stories in the world, and probably the most exhaustively studied by scholars over the centuries” (Lewis 2006: 4). Published stories of deluge events have been collected from every continent from both inland and coastal areas (Frazer 1916, 1919). Scholarship in western society has often approached the near-universal occurrence of these stories as they relate to the Noah's account of the biblical flood (Dundes 1998; Frazer 1919; Gillepsie 1951; Gould 1998; Lewis 2006). Indeed, it has even been suggested that Tlingit and Tsimshian stories of sea level change have a common origin somewhere in the “Old World”, possibly the Middle

East (Goodchild 1991). Other researchers are less willing to attribute the widespread occurrence of this mythical motif as resulting from a single flood event:

There is not one deluge legend, but rather a collection of traditions which are so diverse that they can be explained neither by one general catastrophe alone, nor by the dissemination of one local tradition alone. Some are highly imaginative but wide-of-the-mark attempts to explain local topographic features or the presence of fossil shells high above sea level. A large number are recollections – vastly distorted and exaggerated, as is the rule in folklore – of real local disasters, often demonstrably consistent with special geological conditions [Vitaliano 1973: 178].

Following this, it is contended here that the near-universality of deluge stories is not the result of one worldwide event, but rather the widespread occurrence of flood events as a geological reality. Although some stories may have borrowed elements from one another, many are based on distinct local sources.

Whereas narratives of flood events rely on the passing of oral or textual traditions from one generation to the next, geology observes and measures physical evidence of different sea levels. Geological research reveals that sea level fluctuations occur on global and local scales and will have significant implications not only for past populations but also for modern and future populations (Douglas et al. 2001; Peltier and Fairbanks 2006; Pirazzoli 1996).

The discipline of geology was in part founded in attempts to demonstrate physical evidence of the all-destroying biblical flood (Gillispie 1951). However, with Agassiz's identification and characterization of the glacial epoch, more parsimonious means of accounting for the physical evidence of sea level change were generally adopted. It is in

consideration of glacial epochs that much geological research into sea level has been elaborated upon for the past 150 years. As a result, the relationship of glaciation and sea levels has become critical to modern geological research dealing with the Quaternary period:

Sea-level changes since the last glacial maximum have varied greatly from place to place. Formerly glaciated areas, when unloaded of ice, have generally shown a relative sea level fall, often of the order of hundreds of meters. Oceanic waters, which received the meltwater from icesheets, have been deepened by glacio-eustatic rise. The ocean floor has been depressed by the meltwater load. Coastal areas have reacted to the sea-level rise in a very variable manner, depending on their distance from former ice sheets, local topography and water depth [Pirazzoli 1996: 3].

Variability in sea level change makes it difficult to predict the elevation of past sea levels at particular locations without gathering evidence from that location. Furthermore, because of this variation, evidence of relict shorelines must be dated on a local scale.

Archaeologists have been drawn towards research regarding past sea levels and their effects on human populations and archaeological site locations. Indeed, after geologists more or less abandoned biblical explanations to account for evidence of higher sea levels, archaeologists began the search for flood events. In 1872, George Smith translated a part of the epic of Gilgamesh from an Assyrian text (found in what is now Iraq). This story, considered to be older than the Hebrew Old Testament, related an event very similar to that detailed in the story of Noah's Flood. Excitement around this began the archaeological tradition of searching for evidence of 'The Deluge' (Flemming 1971; Frazer 1916). In contrast to the amassing of evidence for a widespread flood undertaken

by early geologists, these archaeological investigations were conducted on a more regional or localized scale, being limited, at first, to the Fertile Crescent of southwest Asia. High profile searches for cities under the sea, such as Atlantis or Lemuria, have brought about subsequent archaeological research into flood events (Flemming 1971).

Research undertaken by archaeologists, aided by the development of scuba and submarine technology, has found evidence of people inhabiting relict shorelines at different elevations at many different times in the past in many different part of the world (e.g., Clottes and Courtin 1996; Flemming 1971; Masters and Flemming 1983; Muckelroy 1980). From the evidence presented in these studies, as with the evidence derived from comparative folklore and the geological record, it is clear that there have been multiple flood events that are associated with human history and that it is important to consider the relationship of archaeological sites to sea level on a regional or localized scale.

Episodes of sea level rise and fall can occur over short-term periods (minutes to years) through to very long term periods (millennia to millions of years). Sea level changes can be cyclical and non-cyclical. For example, while the tide ebbs and flows cyclically over a short time-scale, tsunami events are not predictable in the same manner. It should be noted that short-term unpredictable changes in sea level are most likely to create catastrophic conditions. As a result, these types of events may be the most likely to be preserved through the transmission of oral history. These events are also likely to have a lesser geological visibility as a result of their short duration. In contrast to this, longer-term changes in shoreline will have a less catastrophic effect on coastal inhabitants. However, with extended periods of accumulation and erosion these events

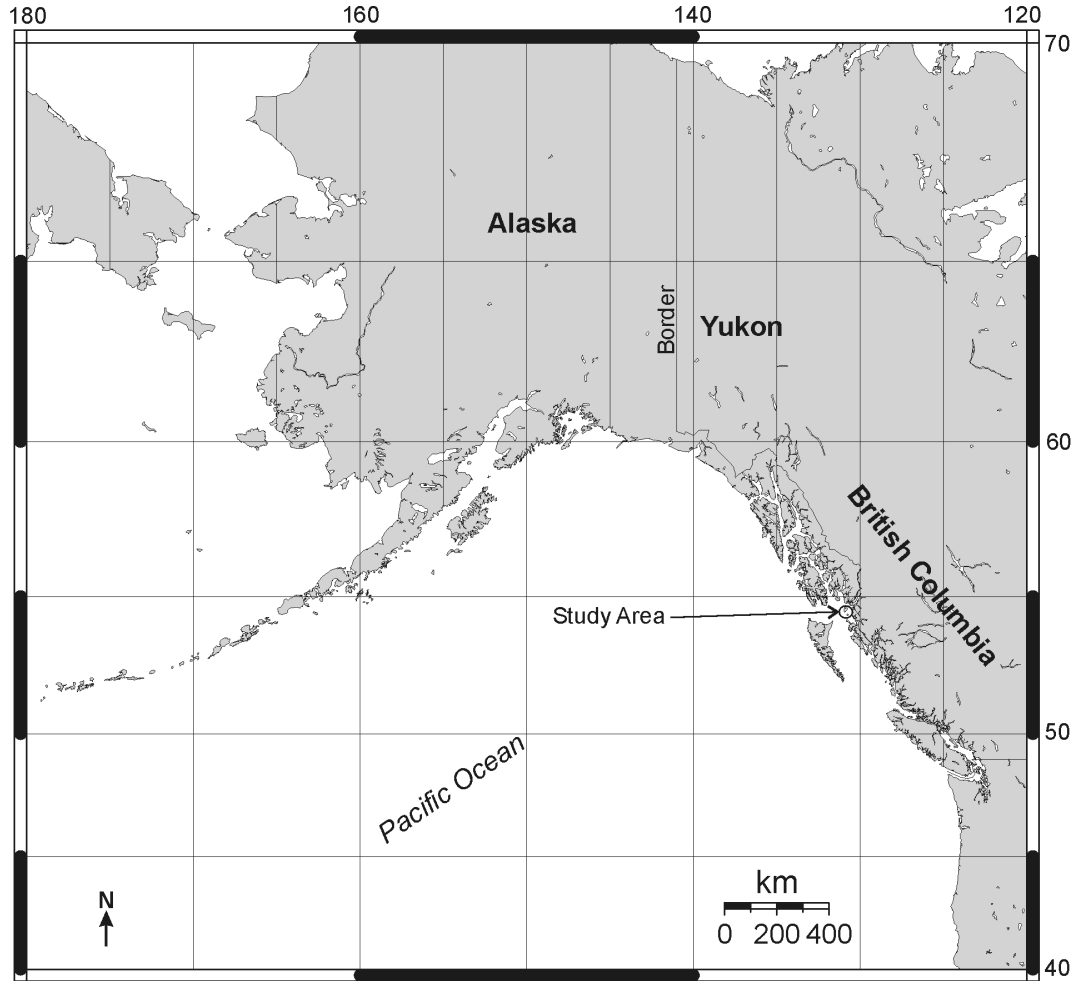
will be more readily identifiable in the geological record. Thus, stories based on geological evidence, such as sediments with shells above the present shoreline, have a greater likelihood of relating to long-term shifts in relative sea level as the physical remnants are more likely to be noticed and incorporated into oral histories as a means of confirmation and as mnemonic devices.

Overall, the goals of this dissertation are archaeological. Regarding sea levels, coastal archaeologists must adopt some basic assumptions. First, shorelines are not stable. Changes in shorelines that are most visible in the geological record tend to reflect long-term processes. Patterns of the human experience of massive changes in sea levels are often left in the archaeological records. At the most basic level this can be exemplified through the locations of human coastal settlements at different times. In the case of gradual sea level regression in regions where human settlement occurs adjacent to shorelines, archaeological sites will have a tendency to be stranded inland. In areas where gradual sea level rise events have occurred, archaeological sites will tend to be stranded tidally or sub-tidally and settlement relocated above the tidal margin.

Rationale for Research

The primary goal of this dissertation project was construct a landscape model to guide a search for late Pleistocene and early Holocene archaeological sites on the Dundas Island Archipelago (Figure 1). The study area was chosen as a result of the hypothesis that late Pleistocene and early Holocene shorelines in the region were only a few metres higher than present-day sea level as a result of global eustatic and local glacial isostatic processes. Similar to a hinge, the study area lies between two adjacent regions with

Figure 1. Location of the Dundas Island Archipelago study area on the Northwest Coast of North America.



markedly different sea level histories. To the east, the mainland of North America was isostatically depressed during the last glacial maximum. Sea levels along the coastal margin of this region, following deglaciation, were up to 200 m higher than present (Clague 1984). As a result of the horizontal displacement of subcrustal material, areas to the west of the study area bulged upwards resulting in lower sea levels (Clague et al. 1982). With sustained deglaciation of the continental glacier on the mainland, sea levels dropped as the crust rebounded faster than eustatic sea level rise. On the outer coast, sea levels rose as a result of glacial eustasy combined with the collapse of the forebulged area.

The search for a sea level hinge between these two regions is significant for archaeological research problems. The Northwest Coast¹ of North America, between the Alaska Peninsula and south coastal British Columbia, is hypothesized as a route by which people from Northeast Asia populated the Americas at the end of the last glacial maximum (Fladmark 1979). There are currently no archaeological sites in the Americas that are widely accepted as dating to the period before the late-Wisconsinan glaciation (Madsen 2004a). Generally, archaeologists appear to be more willing to accept the first bonafide archaeological evidence for the human occupation of the Americas as occurring between 12,500 and 11,500 BP² (Dixon 1999; Fedje et al. 2004a; Meltzer 2004). In light of the archaeological evidence amassed to date, it appears that the first migrants to the Americas arrived sometime at the end of the late-Wisconsinan glacial period.

Whether the Northwest Coast provided an initial migration route into the Americas is a topic of debate among archaeologists (Dixon 1999; Easton 1992; Fedje et al. 2004a; Fladmark 1975, 1979; Mandryk et al. 2001; Meltzer 2004). Even though much of the outer coast was deglaciated by 14,000 BP (Clague et al. 2004) this area has now been flooded by 120 m of eustatic sea level rise (Fairbanks 1989) and forebulge collapse (Clague et al. 1982), thus confounding field work logistics aimed at finding evidence of the earliest occupants of this region (Fladmark 1979). The shorelines of Beringia to the north, and western Washington and Oregon to the south were not glaciated and have been submerged by post glacial eustatic sea level rise (Davis et al. 2004; Hopkins 1996).

¹ 'Northwest Coast' refers to the Northwest Coast culture area, generally characterized by anthropologists as stretching along the Pacific margin of North America from the Copper River delta on the Gulf of Alaska to the Oregon/California border. "Culturally the Northwest Coast is as distinct as it is environmentally" (Suttles 1990: 1).

² All dates used in this dissertation are in uncalibrated radiocarbon years before present unless indicated otherwise. Where it is applicable, marine reservoir corrections have been applied. A table of date calibrations is presented in Appendix A.

In contrast to these now flooded regions, parts of the Northwest Coast were isostatically depressed by the load of continental ice during the last glacial maximum. Sea levels along isostatically-depressed shorelines were higher than today at the end of the last glaciation. With deglaciation, isostatic rebound contributed to keeping several of these elevated relict shorelines above the present-day sea level regardless of the 120 m of eustatic sea level rise (Clague et al. 1982; Clague 1984; Fedje et al. 2004a; Fedje et al. 2005b; James et al. 2002). In some of the inner waterways, such as Kitimat Arm and the Fraser Valley, sea levels were 200 m or more higher than today at terminal Pleistocene times (Clague 1984; James et al. 2002). During the late Pleistocene and into the early Holocene these shorelines plummeted, generally reaching present-day sea level after 8,000 BP (Fedje et al. 2005b; James et al. 2002). It is likely that people living in these areas would have been drawn to move repeatedly over the course of this shoreline regression rendering coastal archaeological residues thinly dispersed.

The effects of late-glacial sea level change continued well into the early part of the Holocene period with continued isostatic adjustment and eustatic sea level change (Fairbanks 1989). By the mid Holocene, these processes appear to have slowed and sea level change during this time is mainly attributed to tectonic activities (Fedje et al. 2005b). In Coast Tsimshian Territory, this is when the first archaeological evidence appears along the present shoreline (Ames 2005; Fladmark et al. 1990). Archaeological deposits dating since 5,000 BP in the Prince Rupert Harbour region have become some of the most intensively investigated on the Northwest Coast (Ames 2005; Archer 2001; Cybulski 2001; Eldridge and Parker 2007; Fladmark et al. 1990; MacDonald 1969; MacDonald and Cybulski 2001; MacDonald and Inglis 1981; Martindale and Marsden

2003). Before 5,000 BP, there are no archaeological contexts known, leaving a gap in the cultural historical sequence of the region between the time that the area was hypothesized to have been first inhabited, following the late glacial maximum, and 5,000 BP (Fladmark et al. 1990; Coupland 1996). In reference to this gap, Fladmark et al. (1990) suggest that it is possible, though unlikely, that the area was not inhabited during this period.

It is because of this gap in the archaeological record that the potential of relatively stable late Pleistocene and early Holocene shorelines on the Dundas Island Archipelago becomes significant. Unlike areas to the west of the study area, late Pleistocene shorelines were not inundated rendering them less logistically difficult to access. Unlike areas to the east, shorelines dating to the late Pleistocene were not 200 m above present shoreline and should be relatively accessible from the present shoreline. Furthermore, the stable sea levels in the area may have resulted in a more stable pattern of shoreline-oriented occupation allowing for the accumulation of archaeological deposits over long periods of time. For this reason, early Holocene archaeological deposits could be expected to occur near middle and late Holocene accumulations.

In light of these expectations, this dissertation project sought to address two primary hypotheses.

- 1) The Dundas Island Archipelago lies near a sea-level “hinge” region of north coastal British Columbia.
- 2) Archaeological sites dating to the late Pleistocene and early Holocene could be found on the relatively stable shoreline of the sea level hinge.

To test these hypotheses, three stages of research were designed and undertaken on the Dundas Island Archipelago.

- a) The identification and characterization of relict shorelines and creation of a relative shoreline curve.
- b) The gathering of geographic data in order to model and map areas where archaeological sites would be expected to occur.
- c) Testing the model through archaeological prospection specifically oriented at discovering late Pleistocene and early Holocene archaeological sites.

These stages were based on similar research oriented at discovering early Holocene archaeological sites on Haida Gwaii³ (Fedje and Christensen 1999), on the Alaska Peninsula (Jordan 2001; Jordan and Maschner 2000), and on the central coast of British Columbia (Cannon 1999). Additional direction was taken from Fedje et al. (2004a) who present an outline of late Pleistocene archaeological research potential for the east side of Hecate Strait.

Study Area

The Dundas Island group is a small archipelago of islands located on the outer mainland coast of British Columbia, 1.6 km south of the boundary between southeast Alaska and British Columbia (Figure 2 and Figure 3). This archipelago is separated from mainland British Columbia by 14 km of open water named Chatham Sound. Directly to the west of the islands is Dixon Entrance, a large passage that lies between Graham Island to the south and Prince of Wales Island to the north. To the southwest of the

³ Commonly referred to as the Queen Charlotte Islands.

Dundas Islands is Hecate Strait, which separates the mainland of British Columbia from Haida Gwaii to the west.

Figure 2. Location of the Dundas Island Archipelago, Hecate Strait, and Dixon Entrance.

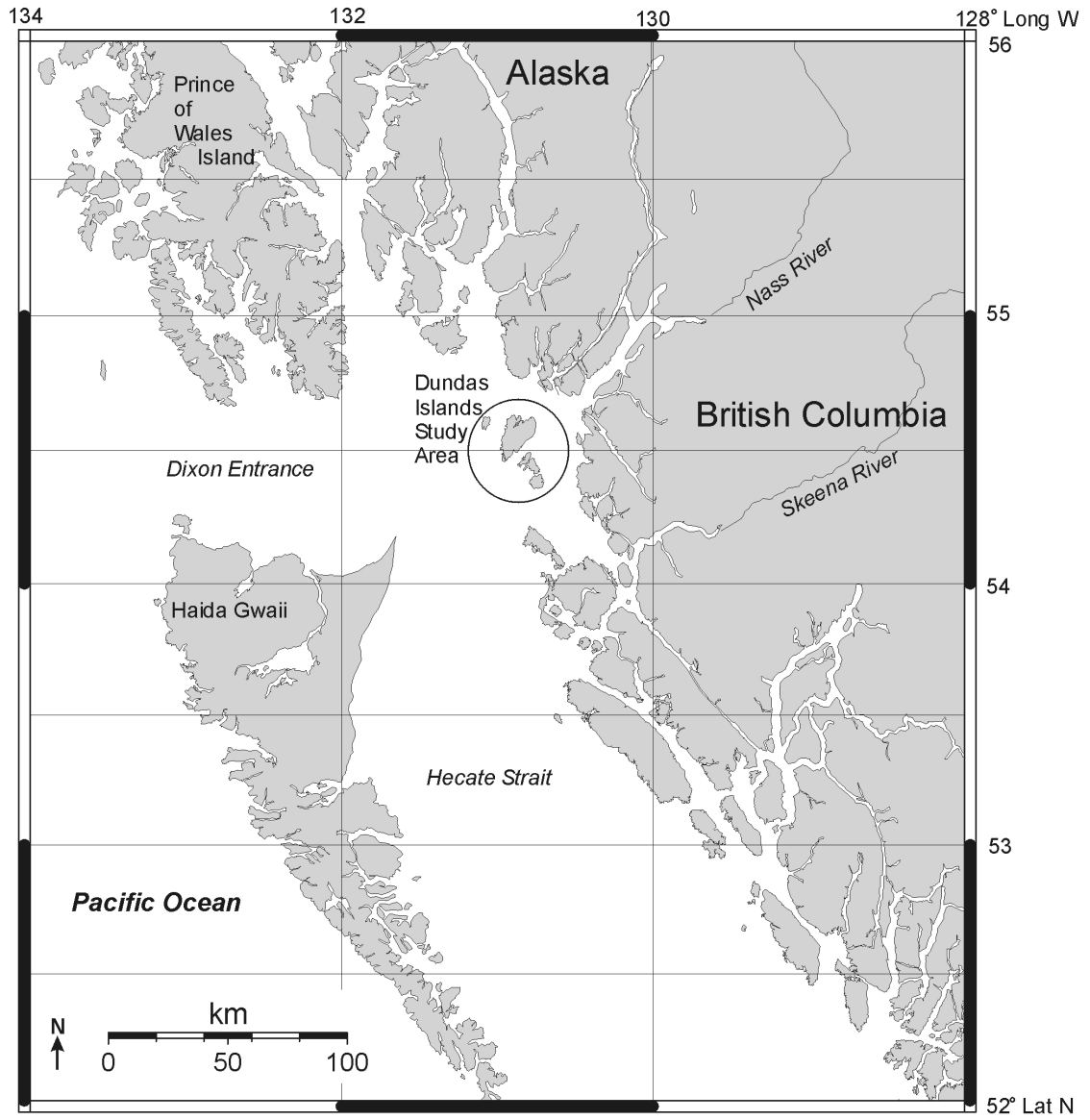
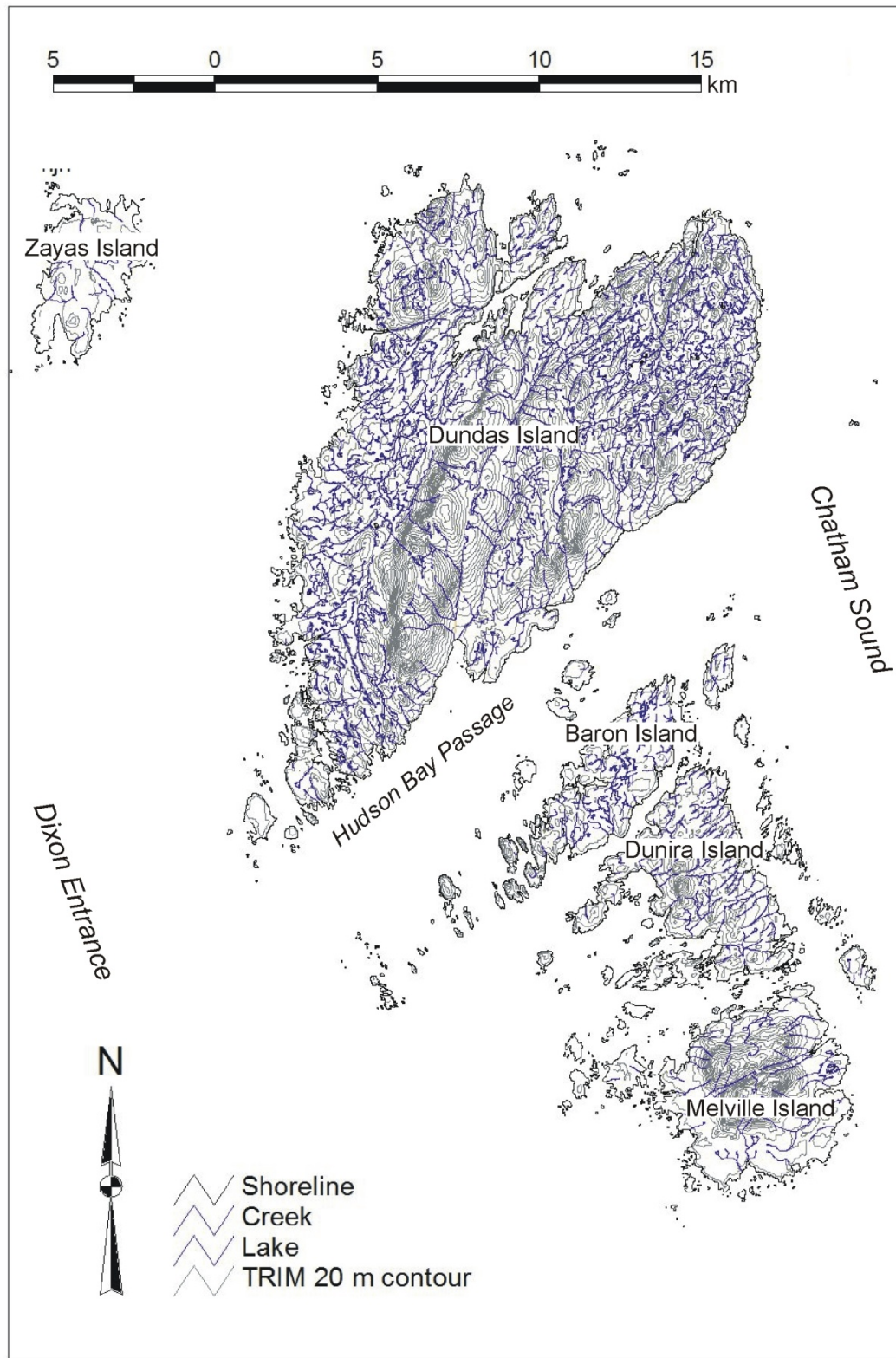


Figure 3. Map of the Dundas Island Archipelago showing the names of the major islands.



Five main islands form the Dundas Island group: Dundas Island, Zayas Island, Baron Island, Dunira Island, and Melville Island (Figure 3). Hundreds of smaller islets and skerries are found around these larger islands forming a total shoreline length of 640 km over an area that spans 32 km of coast, measured as the crow flies in a line from southeast to northwest.

The tidal fluctuation in the region is diurnal and is 7 m from maximum low tide to maximum high tide. The combination of the crenulated shoreline morphology, large tidal fluctuation, flat topography, and strong currents, has resulted in a large and highly productive intertidal zone. Intertidal species include horse clam (*Tresus nuttallii*), butter clam (*Saxidomus giganteus*), littleneck clam (*Protothaca staminea*), bay mussel (*Mytilus trossulus*), and giant barnacle (*Balanus nubilis*) amongst others.

Maritime species typical of northeast Pacific waters are found in the waters off the Dundas Islands. A *Eumetopias jubatus* (Stellar sea lion) rookery is located near the southwestern end of Dundas Island. *Phoca vitulina* (harbour seal), Phocoenidae (porpoise species), *Eschrichtius robustus* (grey whale), *Orcinus orca* (orca), and *Megaptera novaeangliae* (humpback whales) frequent the water. The northern end of Dundas and Zayas Islands are renowned Salmonidae (salmon) salt water fisheries and there are a few small spawning streams. *Hippoglossus stenolepis* (halibut), *Clupea harengus pallasii* (herring), *Hexagrammos* species (greenling), Gadidae (cod), and *Sebastes* species (rockfish) are just some of the fish species in the water that surrounds the islands.

The highest point of land on the Dundas Islands is Mt. Henry, at 444 m above sea level, but most of the islands lie below 100 m elevation (Figure 4 and Figure 5).

Figure 4. View of the flat topography of Baron Island.



Figure 5. View of intertidal zone and steep area on Melville Island.



Extensive peat bogs characterize the relatively flat and gently sloping areas. The Dundas Islands are classified as “Coastal Western Hemlock very wet hypermaritime biogeoclimatic subzone” (CWHvh2) (Meidinger and Pojar 1991). Climax vegetation is dominated by forest species typical of this biogeoclimatic subzone including *Thuja plicata* (Western red cedar), *Alnus rubra* (red alder), and *Tsuga heterophylla* (coastal western hemlock) in well-drained areas. The study area lies just north of the northern range of *Abies amabilis* (amabilis fir) and this species was not noted on the island. *Picea sitchensis* (Sitka spruce) is rare. Flat and poorly drained areas are widespread and characterized by *Sphagnum* moss accumulation and associated scrub *Pinus contorta* (lodgepole pine) and *Chamaecyparis nootkatensis* (yellow cedar).

It is likely that these islands have been separated from the mainland since the time of the last glacial maximum. The terrestrial fauna is very limited because of this isolation and the small land size of the islands. Land mammals noted on the islands include *Lontra canadensis* (river otter), *Mustela vison* (mink), *Martes americana* (marten), *Castor canadensis* (beaver), and *Microtus longicaudus* (long-tailed vole). *Canis lupus* (wolf), which now inhabit the islands, was introduced sometime in the 1980s (David Archer 2004, personal communication).

Hutchison (1982) mapped the bedrock geology of the Dundas Islands. The western side of the islands is characterized by plutonic granodiorite and quartz diorite, while the eastern side of the islands has early Mesozoic and/or Palaeozoic volcanic rocks which are weakly metamorphosed including volcanic breccia and schist. Meta-sedimentary rock is also found in this unit on the east side of the islands, which includes limestone, banded quartzite, and graphitic slate.

The general topography of the islands is the result of past glacial epochs. Maps showing the extent of glacial ice during the late-Wisconsin glaciation (the last glacial maximum, ~18,000 BP) illustrate the Dundas Islands as being overridden by ice (Barrie and Conway 2002b). Major outlets for glacial ice flowing from the interior west towards the coast include the river valleys of the Skeena, Nass, and Stikine river systems (Spooner and Osborn 2000; Stumpf et al. 2000). Surficial geology maps of the Queen Charlotte Basin demonstrate glacial features in Queen Charlotte Strait, Hecate Strait, and Dixon Entrance (Barrie and Conway 2002a), including moraines and iceberg scours. The moraines demonstrate that tongues of Cordilleran ice flowed well into Hecate and Queen Charlotte Strait, in particular where major drainages lead from the mainland. Additional morainal features are mapped in the western end of Dixon Entrance. Although none of these features has been dated, they are attributed to the last glacial maximum (Barrie and Conway 2002b).

From aerial photographs (BC77008 #67-#104) of the Dundas Islands, linear patterns, similar to glacial fluting, are visible. The highest promontories on the islands are rounded and the highest point on Dunira Island has the appearance of being plucked on the western side. These features suggest that the islands were over-run and carved by glacial ice at some time in the past.

It is speculated that the Hecate lowlands are strandflats (Mathews 1989). Strandflats are low lying, flat coastal regions that flank steep mountain ranges which have been glaciated. The low coastal strandflat that is found along the study area is a “low coastal rock platform abutting against a sharply rising mountain slope” (Mathews 1989: 33). This strandflat has been referred to as the Milbank Strandflat (Ryder 1986) and is

also referred to as the Hecate lowlands (Clague 1984). Strandflats are characterized by low-lying topography, multiple islands and skerries separated by inlets and passages. This landform may have been partially created by the presence of abundant moisture and poor drainage during the Pleistocene.

The formation processes of strandflats are not well understood, but they are found in regions of high latitude where there are interactions between marine and glacial conditions (Guilcher et al. 1994). In general, frost shattering of surface materials during cold periods loosens bedrock that is removed by marine processes at sea level (Peulvast 1994). Over long time periods, this process can create large, flat or slightly sloping areas. In some regions, overriding piedmont glaciers may further alter the topography (Moign and Guilcher 1994).

Previous Archaeological Research

Archaeological research conducted on the Dundas Islands is essentially still in its infancy. Most research undertaken to date has been oriented towards archaeological survey, site mapping, and preliminary subsurface testing (e.g., Fedje et al. 2004b; Haggarty 1988; Ruggles 2007). Very little of this work has been reported, and very few British Columbia site inventory forms have been completed.

Preliminary archaeological reconnaissance of the Islands was undertaken in 1975 by Richard Inglis from the National Museum of Man, Ottawa. The Zayas Island project was an extension of this work undertaken in 1987 by Dr. Jim Haggarty of the Royal British Columbia Museum. It focussed on the preliminary recording of archaeological sites on Dundas Island, the Nares Islets, and Zayas Island (Haggarty 1988). Most of the sites recorded are cabins, large shell midden-based villages, and

petroform fish traps. In 1998, David Archer from Northwest Community College (NWCC) began a program aimed at inventorying archaeological sites on Melville and Dunira Islands. This research focussed specific attention on recording and mapping large villages.

Field results drawn upon in this dissertation stem from research undertaken between 2001 and 2006. In 2001, the environmental archaeology work was commenced by Daryl Fedje (Parks Canada) and Dr. Quentin Mackie (University of Victoria) (Fedje et al. 2004b). Archaeological research was continued between 2004 and 2006 in association with a larger archaeological survey and mapping-based project undertaken by David Archer and Dr. Andrew Martindale (University of British Columbia). During the course of this research two archaeological field schools were run in 2005 from NWCC and in 2006 from UBC.

Overall, a combination of glaciation, shoreline erosion and deposition, tectonics, rainfall, biological succession, and human inhabitation has contributed to shaping the study area as it is currently found. This dissertation adds to the characterization of the study area palaeo-environmentally through the reconstruction of vegetation and sea-level histories, and archaeologically through site discovery and testing.

Organization of Dissertation

Following this introduction, Chapter II summarizes ethnographically collected information on the study area. Included is an investigation of the oral history of flood events described in the ethnographies of northern Northwest Coast ethnolinguistic groups.

Chapter III summarizes palaeo-environmental research on the northern Northwest Coast with a specific focus on deglaciation following the last glacial maximum, and the associated isostatic and eustatic factors. The length of time that the region has been deglaciated, and the types of ecosystems that occurred in the past are also considered in this chapter.

Chapter IV summarizes archaeological research that has been undertaken on the northern Northwest Coast. In particular, this chapter reviews the locations of late Pleistocene and early Holocene archaeological sites in relation to sea level histories. The chapter also examines the types of archaeological material found at late Pleistocene and Holocene archaeological sites in other parts of the Northwest Coast. This chapter emphasizes the utility of having a well defined and localized sea level history prior to embarking on archaeological survey for early period archaeological remains.

Chapter V focuses on palaeo-environmental reconstruction of the study area, in particular, the methods and results used to construct a chronological sequence of vegetation communities for the Dundas Islands. This work is based on pollen analysis undertaken on a core from a lake on Dundas Island.

Chapter VI details the methods and results used to reconstruct a sea level history for the Dundas Islands based on the investigation of landforms, sedimentary exposures, and isolation lake basin coring. A sea level curve for the study area is presented.

Chapter VII details the data collected and created in order to model specific areas where archaeological sites would be likely to occur on relict marine features. A number of different geographic data sources were drawn upon in order to select areas for archaeological survey. Key to this exercise was the creation of 2 m contour maps from

which past shoreline locations could be predicted drawing upon the sea level curve constructed in Chapter VI.

Chapter VIII presents the methods and results used to test the model through archaeological prospection undertaken. Elevations and radiocarbon dates of archaeological deposits encountered are presented.

Chapter IX brings together the ethnographic, palaeo-environmental, and archaeological data. These multiple long-term histories are contrasted and compared. An evaluation of the limitations of the research is presented and possible directions of future research based on the results of this project area are considered.

Chapter II – Ethnographic Context

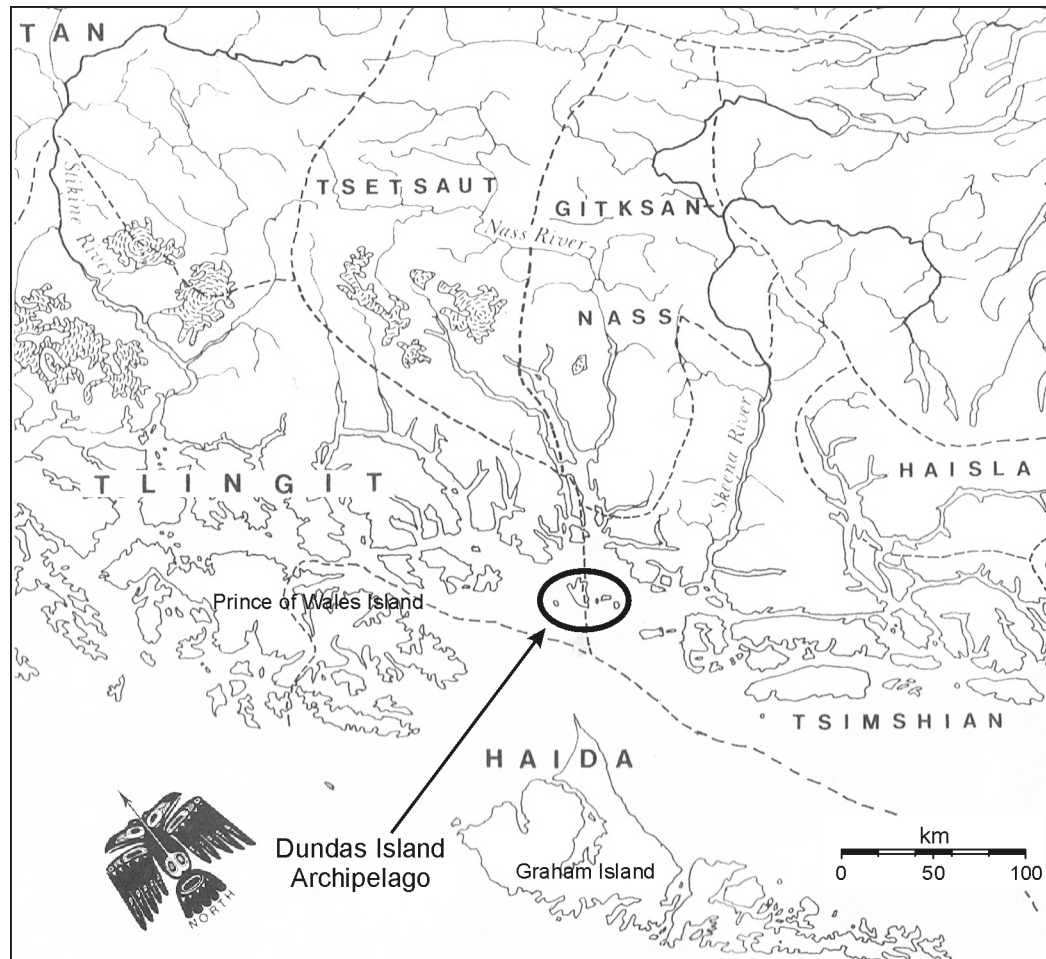
Introduction

The Dundas Island Archipelago lies at the northwesternmost boundary of Coast Tsimshian Territory (Figure 6). The territory of Nisga'a speakers, a sister language of Coast Tsimshian, lies directly to the east and inland of the coast and is generally associated with the Nass River watershed. Also inland of the coast, but centred along the course of the upper Skeena River lies the territory of the Gitksan. The Coast Tsimshian, Nisga'a, and Gitksan are related linguistically and culturally, and are referred to collectively as the Tsimshian (e.g., Boas 1916; Halpin and Seguin 1990). Coast Tlingit territory is to the north of the Dundas Islands in southeast Alaska, and Haida groups are to the west on the island Archipelago of Haida Gwaii as well as Prince of Wales Island. Ethnographers have written that these three distinct coastal ethno-linguistic groups share a number of unique culture traits not found elsewhere in the Northwest Coast culture area, in particular, their complex matrilineal clan organization and exogamous phratries (Garfield and Wingert 1966).

Different Northwest Coast culture area maps place the Dundas Islands in various cultural contexts. Some illustrate the Dundas Islands in Tsimshian territory (Halpin and Seguin 1990), while others (Suttles 1978) draw a Tlingit/Tsimshian boundary directly through the Dundas Island group (Figure 6). Some researchers do not place distinguishing boundaries between these linguistic groups but identify them by title only (Campbell 2005; Garfield and Wingert 1966). Tlingit and Tsimshian oral histories

recognize that both groups have occupied the Dundas Islands at different times (Marsden 2000, 2001).

Figure 6. Detail of Suttles (1978) map of linguistic groups and territories of the Northwest Coast (with modification).



According to Tsimshian and Tlingit oral historical records, at some time in the past, warfare between the groups resulted in the relinquishing of villages in the Dundas Islands by Tsimshian speakers or at least the community's elite (Boas 1916; Cove and MacDonald 1987; Haggarty 1988; Marsden 2000). The Tlingit migrants took up residence on the Dundas Islands and began staging raids on other Tsimshian villages to the south in Prince Rupert Harbour. Following this, the main Tsimshian clans retreated to the lower Skeena River area and regrouped. Subsequently, the Tsimshian moved back

into the Prince Rupert Harbour area, pushing the Tlingit to the north. The majority of the Coast Tsimshian established themselves in Metlakatla Pass, resulting in the very high density of village sites in the area (Archer 2001). It is uncertain to what degree the Dundas Islands were re-occupied by the Tsimshian.

What is clear from the wealth of ethnographic data collected during the first half of the 20th Century is that both Tsimshian and Tlingit groups claim all or a portion of the Dundas Group as part of their traditional territory. In 1915, Benyon recorded that the Dundas region was part of the territory of GITZAKLALTH Tsimshian. This group, unlike other Tsimshian groups, had only two clans (raven and wolf) rather than the usual four – a trait characteristic of the Tlingit rather than the Tsimshian. In addition, many of the village names were Tlingit names and their chiefly house was associated with a subgroup of the Tongass Tlingit [Haggarty 1988: 9].

From the Tlingit perspective the Dundas Island Archipelago was occupied by the Tanyakwan or Sanyakwan Tlingit in the past, and by the Tongass before they were forced to move northwards after the creation of the Alaska-British Columbia border (Olson 1967; Haggarty 1988). Like many linguistic border regions of the Northwest Coast, the Dundas Islands may have been linguistically intermixed at various times.

Seasonal Rounds

MacDonald describes the seasonal rounds that were used by Coast Tsimshian groups (as recorded ethnographically) in the following manner:

Most tribes followed a seasonal cycle of resource exploitation that took them from their winter villages early in April to the oolachen fishing on the Nass; in late spring they moved to the lower Skeena villages for the

salmon runs lasting through most of the summer. The men left for the hunting grounds in the fall and in November they returned, with their families, to the villages in the protected Rupert Harbour, where shellfish were a main item of the diet [MacDonald 1969: 240].

Table 1 presents a summary of Coast Tsimshian seasonal rounds based on ethnographic descriptions (Garfield and Wingert 1966; Halpin and Seguin 1990; MacDonald 1969).

Table 1. A summary of Coast Tsimshian seasonal rounds as described in ethnographic records.

<i>Season</i>	<i>Place</i>	<i>Resource</i>
February-April	Nass River	Oolachen
May	Coastal islands and inner waterways	Seaweed, halibut, herring, bark and pitch collection
Early June	Coastal islands and inner waterways	Seagull and oystercatcher eggs, abalone
June-October	Skeena River	Salmon fishing, processing, storage
September-November	Tidal zone, interior regions	Hunting land mammals, sea mammal
December-February	Winter Villages	Shellfish harvesting, ceremonials, feasts

From both oral historical and archaeological sources it has been suggested that this specific pattern of seasonal mobility has limited time depth, primarily as a result of the conflict related population movements between 2,000 BP and 1,500 BP (Martindale and Marsden 2003).

At least since the creation of the international (Canada/Alaska) boundary, the Dundas Islands have been used seasonally by Tsimshian people from Lax'Kw'alaams and Metlakatla with activities focusing on seaweed harvesting, seal hunting, and halibut fishing in the spring, and trapping beaver, mink, and river otter in the winter (Haggarty 1998). Seventeen Indian Reserves and a number of cabins are located on the islands, many of which continue to be used for these seasonal harvesting activities.

The oolachen run on the Nass River was a very important seasonal event socially and economically (Halpin and Seguin 1990). Historically, Tsimshian groups that used the fishery used the rendered grease as a lucrative trade commodity. From the Nass, grease was traded to outer coastal areas where oolachen runs are absent. Traveling from the Nass through Portland Inlet to outer coastal areas, in particular Graham Island and Prince of Wales Islands, requires passage via the Dundas Islands.

Oral Tradition and Sea Levels

Narrative-based analyses have demonstrated correlation between late Pleistocene and early Holocene events described by geologists and oral history in Haida Gwaii (Fladmark 1989; Kii7iljuus and Harris 2005), Bella Coola (Hall 2003), and the Fraser Valley (McLaren 2003). Importantly, oral history is not dateable using scientific methods such as radiocarbon dating. This does not mean, however, that these histories are atemporal. Oral narratives are often organized into a sequence of events. Specific linguistic devices may be used to orient an event temporally by indicating if it occurs before, during, or after a temporal marker (Martindale and Marsden 2003; McLaren 2003). The temporal markers used to reference stories are often profound changes that occurred in the past, and these can be environmentally related. In some instances, physical remnants of these events are described on the landscape as a testimony of the event. In this manner an order of major events is strung together in a coherent and recognizable sequence.

Miller (1997) described two different oral narrative traditions associated with the Coast Tsimshian: the Raven cycle, and the *adawx*. Amongst the Tlingit the *adawx* are

referred to as *at.oow* (Marsden 2000), and amongst the Haida as *q'ayaagaand* (Enrico 1995). Boas (1916) and Miller (1997) distinguished Raven stories as being commonly held creation narratives. In contrast to this, the *adawx* are stories relating the lineage histories of different kinship groups and are the property of the chiefs who tell them during feast times (Marsden 2000). Significantly, the Raven stories tell of the historical events that shaped the world, whereas the *adawx* and *at.oow* relate the history of a lineage and its rights to specific crests, resources, and territory.

Many of the *adawx* of the Tsimshian and *at.oow* of the Tlingit recall the migrations of clans from the interior to coastal areas (Cruikshank 2005; Marsden 2000). While not all of the *adawx* or *at.oow* reveal an interior origin for the Tsimshian and Tlingit groups (MacDonald 1969; Emmons 2000), many lineages relate that they migrated from the headwaters of the Stikine, Nass, and Skeena Rivers to the coast after social and supernatural disagreements, or environmental calamities, forced the peoples to move (Marsden 2001).

In contrast to this interior orientation, the Raven Cycle reveals a prominent coastal setting. In regards to the Raven Cycle, Boas made the following remarks:

The Raven myth of the Tsimshian is quite similar to that of the Tlingit and Haida. Among these tribes most of the incidents that compose it are the same, and a few even occur in the same arrangement. Although many of these have a much wider distribution, the myth, with its elaborate introduction, is confined to the three coast tribes just mentioned, including, however, probably the Athapascan tribes immediately to the east of the Tlingit and Tsimshian. Among all of them it comprises the incidents that led to the establishment of the

present world, and begins with the supernatural origin of Raven [Boas 1916: 629].

Miller (1997) suggests that amongst the Tsimshian the Raven or Giant is a *naxnox* (wonder) from heaven and that was adopted from the Haida.

Boas (1916) compared the Raven cycles of the Tlingit, Haida, and Tsimshian and found many similarities and some differences (Table 2). All of them have a similar beginning:

Common to all the versions is the initial scene after Raven's return from the sky, the world being covered by water. In the Tsimshian legend, this is merely expressed by the fact that the child is found on a bunch of kelp in the ocean [Boas 1916:640].

Table 2. Comparison of Raven Cycle introductions (based on Boas 1916: 638).

Tlingit	Haida	Tsimshian
Jealous uncle kills nephews. His sister swallows stone and gives birth to a boy (Raven)	Child (Raven) of fatherless woman is taken to his uncle.	Child (Raven) of faithless woman born after her death is taken to her husband
	Boy shoots birds	
Seduces uncle's wife	Chews gum to seduce uncle's wife	Chews gum to seduce daughter of Sky Chief
Uncle makes deluge	Uncle makes deluge	
	Boy flies to the sky	
Their child		He marries the Sky Chief's daughter Their child
	Drops down on kelp	Lands on branches (kelp) in the sea
	Is adopted, becomes voracious Makes flood	Is adopted, becomes voracious

Boas emphasizes repetitions of certain events that occur in individual versions of the Raven cycle introduction. An important repetition is that of the Deluge; it occurs twice in the versions of the Haida introduction to the Raven cycle. This observation is uncharacteristic of Boas's approach to oral history, which tends to remove cyclical elements in favour of a single historical trajectory (Maude 2000). In this case, Boas emphasizes that these repetitions are a vital part of the sequence and not an error in telling as the repetition is found in most versions collected by ethnographers.

Bringhurst (2000) presents a thorough analysis of the recordings of Haida oral history as recorded by Swanton (1905). Bringhurst describes a sequence of events in the Raven stories, told by the epic story teller Skaay, that is similar to that of the sequence presented by Boas (1916). Bringhurst maps an entire telling of the Raven cycle, not just the introduction, and suggest that it occurs in five parts or as he refers to them 'movements'. Furthermore, and contrasting Boas's approach, Bringhurst identified all cyclical events as well as the linear structure of the story.

Table 3. Sequence of movements and tallying of cyclical events (cycles represented by numbers) identified in the Skaay's Raven Traveling (based on Bringhurst 2000).

<i>Movement of story</i>	Raven Named	Flood	Raven Reborn	Adoption	Mirror Image	Biting and Chewing	Raven Nameless	Humans	Marriage	Dog	Potlatch	Scab
First	1	1	1	1	1	1						
Second			2			2	1	1	1	1		
Third	2	2	3	2, 3	2			2		2	1	
Fourth	3	3										1
Fifth							2		2		2, 3	2

Bringhurst recognizes three flood events as cyclical occurrences in the narrative. This interpretation differs from Boas's (1916) discussion of only two sequential flood events.

A fourth event of changing ocean levels appears in Skaay's epic (Bringhurst 2000). This is not a flood event, but a massive ebbing that occurs in the third movement, which is followed by a rising of water levels. The repetition and unique character of each of these events stands in contrast to the assertions that the Northwest Coast flood myths are derived from the fertile crescent of Southwest Asia (Goodchild 1991) presumably through encounters with Christian missionaries. Indeed, it is argued here that they reflect the unique geographic and geological setting of a coast that is adjacent to a tectonically and isostatically unstable region.

These stories are not necessarily related to the experience of sea-level rise as a result of isostatic factors alone. Indeed, short-term fluctuations, such as tsunamis, may have a greater impact on the social memory of coastal cultures (eg. Bornhold et al. 2007; McMillan and Hutchinson 2002). In contrast to this, however, longer-term fluctuations are more likely to leave a readily visible sedimentary record, such as is found on the raised marine terraces of Haida Gwaii (Fedje et al. 2005b). Such physical remnants are likely to be included in narratives as evidence and/or mnemonic devices, thus making it more likely that such event will result in a long-term remembrance. In their interpretation of whether Haida oral historical events reflect sea-level rise as a result of isostasy and eustasy or tsunamic events, Kii7iljuss and Harris (2005) list specific narratives with which they draw parallels to tsunami events and others which they associate with sea level rise as a result of isostasy and eustasy. In the case of the stories

that are associated with tsunami events, there is specific mention to a large wave or waves which deluge the landscape. Similarly, Raven's stranding of whales by lower sea-levels, and the subsequent raising of sea level (Boas 1916; Swanton 1905), appears more like a tsunami event.

Discrepancies in localized sea level change resulting from isostatic factors and related oral histories have been hypothesized as occurring in other areas of the globe in which glacial isostasy is key:

The rate of early post-glacial shoreline displacement exceeded 3 m per one hundred years in parts of Norway, and must have been noticeable to Mesolithic people. Fishing/hunting grounds and natural harbours changed and pathways of movement were blocked. However, in a few days' journey, one would reach areas where the opposite was the case, and local traditions would tell that the sea was rising, not retreating. Whether this was the subject of as much debate to Mesolithic people as to present-day scientists, we do not know. But these regional variations in relative sea-level change are likely to have had an impact on Mesolithic worldviews [Bjerck 2007: in press].

It is possible that remnants of similar events on the Northwest Coast have been preserved in the oral historical record where flood stories do feature prominently. The last flood event related in some Haida Raven cycles, referred to as the *Kinggi* flood (Bringhurst 1999; Swanton 1905), occurs after the dispersal of the lineages and the an earlier flood caused by the hat of Raven's uncle *rahllns kun* (Cape Ball). Several researchers have noted the similarities between the timing of the *Kinggi* flood in Haida oral history and the rapid sea level rise that occurred on Haida Gwaii prior to 9,000 BP (Fedje and

Christensen 1999; Fladmark 1989). Indeed, the earliest cultural historical phase on Haida Gwaii is referred to as the Kinggi complex (Fedje and Christensen 1999).

Until 9,000 BP, early inhabitants of Haida Gwaii would have been aware of the average 3 m sea-level rise which occurred every generation. Rising sea levels during this period may also have made shoreline inhabitation more exposed to tsunamic and storm events:

the extremely rapid rate of marine transgression would have had an important influence on adaptive strategies and settlements in the early period. Coast margins used by one generation could often have been unsuitable for the same use by the next generation, and partially drowned within two generations [Mackie and Sumpter 2005].

The evidence of this event is preserved and readily visible in the raised marine terraces found around all of Haida Gwaii. While the layers of elaboration, distortion, and forgetting that are inherent in oral history have obscured the finer details of this flood event, the sequential coincidence of the archaeological record and the Kinggi flood story area striking: the sea level rises after the first people and distinct linguistic groups appear on the landscape.

A completely different flood story is recorded amongst the Tsimshian but does not appear in the Raven Cycle; rather it is a part of the *adawx* (Miller 1997). Several references to this story cite the location as being in the Nass or Skeena River Basin (Barbeau 1953; Boas 1912a; Miller 1997).

These versions originate at Temlaxam, which translates as 'Prairie Town' (Boas 1912a). The location of Temlaxam is unknown and the date at which it was abandoned is

also unknown. In the oral history, it is after the flood and abandonment of Temloxam that the different linguistic groups appear on the coast:

Some people did not perish at this time, yet they were scattered around along here. That was when their tongues were mixed. Before the Flood they had one language; after the Flood, when they were scattered everywhere, their languages were different. Therefore the people along here know that they are relatives, although their languages are different; and they know their crests, Eagle, Bear, Wolf, or Raven, - because they are really come from one town before the Deluge, and they were scattered after the Deluge. Although they do not understand their languages, yet they know by their crests that they are relatives [Boas 1912a: 251].

In comparing sequencing references from Haida and Tsimshian narratives, the Tsimshian flood appears to predate the last Haida flood event in that it is after the Tsimshian flood and before the last Haida flood that the linguistic stocks and lineage crests are spread across the northern Northwest Coast (Table 4).

Table 4. Comparing the sequence of deluge and dispersal events in Tsimshian and Haida Raven cycles.

Tsimshian	Haida
Flood at Temloxam before dispersal	
Dispersal of languages and lineages	Dispersal of languages and lineages
	Kinggi Flood after dispersal

Stories from the Nass and Skeena regarding raised sea level may well be informed, or have been created to explain remnant shell bearing sediments. It is possible that Early Holocene occupants of the region experienced shoreline regression as a result of isostatic rebound. Indeed, sea levels in the Kitimat region fell on average 1 m every

12.5 years between 10,500 and 8,000 BP, a rate that was undoubtedly noticeable and which left remnant shell bearing sediments (Clague 1984) as a testament to the event which has occurred. Whether the Tsimshian flood story is directly related to these events or not is difficult to discern and cannot be confirmed with certainty. In some instances, the catastrophic events which are listed as forcing people from Temlaxam are referred to as an environmental cooling rather than a flood (Boas 1916).

Flood events related in Tsimshian, Tlingit, and Haida narratives are described as being caused by different agents. In most cases, supernatural figures bring about floods often in retribution for offences committed by individuals (Boas 1916; Swanton 1905). One interesting exception is from the Tahltan Raven story. This episode, entitled *Raven Ballasts the Earth* reveals an intimate knowledge of the relationship of the sea level and glacial ice but also includes the intervention of Raven:

After the Great Flood, people were afraid that the earth might tip again, and cause another flood. It was very light in those days, and rolled up and down, displacing the ocean. Water would rush to one place and stay for a while. Then the earth would tip and the water would rush back again. This is said to have happened several times and some people say that the great Flood that destroyed people came about in this way. Therefore, to make the earth secure and steady, Raven put a large piece of ice on the earth to weigh it down and keep it from tipping. Since then the earth has not tipped, and has been steady [Teit 1919: 219].

Similarly, the scientific explanation for changes in sea level in this area relies on the narrative of ice loading and earth tipping, minus the intervention of Raven. Clearly, these

two very different means of inquiring and retelling the events of earth history have striking similarities.

Conclusion

The Dundas Island Archipelago lies in Coast Tsimshian territory and continues to be used by the people of Lax'Kw'alaams. The oral historical record reveals that in the past, these islands have also been used and inhabited by Tlingit speakers.

The oral histories of the Tsimshian, Tlingit, and Haida reveal episodes of flood events. Significantly, the oral histories relate not just one, but in some instances multiple, sequential, flood events. By examining chronological references used by the narrators of these stories, it seems that Tsimshian narratives relate a flood in the interior that occurs before the final sea level rise on Haida Gwaii. The Tsimshian stories reviewed relate that the languages and lineages from the interior dispersed to the coast after the flood episode. The Haida stories reviewed relate the dispersal of Northwest Coast lineage families from the time before the last flood. The relative timing of these events mirror geological descriptions of late Pleistocene falling water levels (or catastrophic flooding) on the mainland and rising sea levels on Haida Gwaii. However, these stories, oral historical and geological, have also been elaborated upon to a degree where such parallels and conclusions can only be made on a speculative basis.

Chapter III – Palaeo-Environmental Context

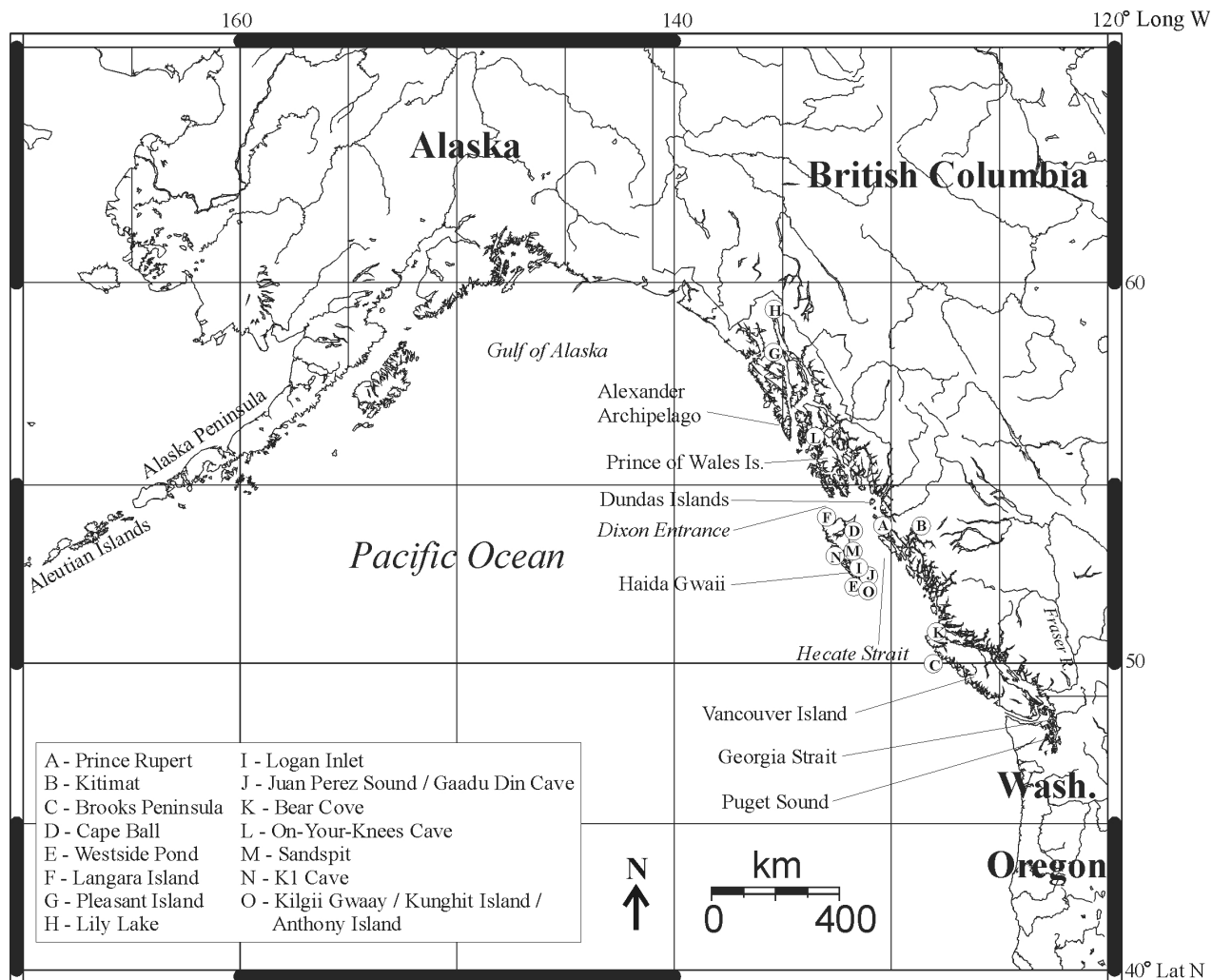
Introduction

The Pleistocene-Holocene transition is characterized by a global environmental shift from a glacial to non-glacial epoch (Clague 2000; Clague et al. 1982; Hebda and Whitlock 1997). During the height of the last glacial maximum (17,000-14,500 BP), along the mountainous terrain of coastal areas between southern Alaska and Puget Sound in Washington State, the Cordilleran Ice Sheet lobes were in contact with the waters of the Pacific Ocean. With subsequent deglaciation, the interactions of the retreating Cordilleran Ice Sheet and rising waters of the Pacific Ocean resulted in a sequence of changing sea levels and environments. This chapter reviews these palaeo-environmental changes as recorded at different localities on the Northwest Coast (Figure 7).

The palaeo-environmental record of the region is of archaeological significance for several reasons. (1) Palaeo-environmental research is necessary to verify the antiquity of archaeological sites dating to the Pleistocene-Holocene transition by demonstrating that the age of archaeological occupation of a site is consistent with the known palaeo-environmental sequence of the region (Dixon 1999). (2) As a result of the dynamic environments (Hebda and Whitlock 1997), human populations in the region needed to be extremely flexible in terms of their adaptive strategies. (3) Due to shifting shorelines, past coastal archaeological sites will not likely be located along present shorelines. In order to find coastal archaeological sites dating to the late Pleistocene and early Holocene, it is necessary to determine the elevations of these shorelines (Fedje and Christensen 1999; Fladmark 1975). (4) Different resources were available to human

populations at different times in the past and palaeo-environmental research can help define resource availability (Lacourse and Mathewes 2005; Wigen 2005).

Figure 7. Northeast Pacific coast, showing geographic areas mentioned in chapter.



The Last Glacial Maximum

Several glacial and interglacial eras characterize the Pleistocene period in the Cordilleran region of northwest North America (Clague 1989a, 1989c). There have been at least eight major climatic cycles in the last 800,000 years and each was likely accompanied by widespread glaciation in the Canadian Cordillera (Clague 2000). The

last major glaciation in the study area is the best known and is referred to as the Fraser Glaciation (Clague 1989b). This glacial interval was global in scope.

At the height of the Fraser Glaciation, the Cordilleran Ice Sheet extended from Northern Washington, Idaho, and Montana to the southern Yukon and southwestern Alaska (Clague 1989a; Clague et al. 2004). East of the Rocky Mountains, the Cordilleran Ice Sheet coalesced with the Laurentide Ice Sheet, a massive glacier spreading west and south from the Canadian Shield. However, the timing of maximum glacial extent varied in different regions. Along Pacific coastal areas of the Cordillera, the maximum glacial extent appears to have occurred at different times in the Georgia Basin region to the south compared to the Hecate Strait region to the north (Barrie and Conway 2002a, 2002b).

By 23,000-21,000 BP an ice sheet covered all of the Hecate Lowlands and valley areas (Clague 1984) and major lobes had pushed through Hecate Strait and Dixon Entrance to the edges of the continental shelf (Luternauer and Murray 1983). From paleontological studies and vegetation reconstruction it has been estimated that the last glacial maximum occurred between 17,000 and 16,000 BP in outer coastal areas (Heaton and Grady 2003; Warner et al. 1982). In this dissertation, the late Wisconsinan maximum refers to this time interval.

In contrast to this northern British Columbia coastal sequence, at the southwestern end of the Cordilleran Ice Sheet, an interglacial period occurred between 18,000 and 16,000 BP at the same time as the Hecate Strait region was undergoing its glacial maximum (Lian and Hickin 1993; Ward et al. 2003). The southern glacial maximum appears to have occurred after this interglacial period between 16,000 and 14,000 BP (Barrie and Conway 2002b; Easterbrook 2003).

Some areas were likely ice-free glacial refugia during the last glacial maximum (Clague et al. 2004; Hebda 1997; Heusser 1989). While no direct evidence of such a refugium has been revealed from a continuous stratigraphic sequence, multiple lines of indirect evidence have been used to support the assertion that glacial free areas, able to support diverse ecosystems, existed: presence of disjunct and endemic plants (Heusser 1989; Ogilvie 1997) and animals (Byun et al. 1997), geological evidence (Barrie and Conway 2002a; Josenhans et al. 1995; Warner et al. 1982), palynology (Hebda 1997; Warner et al. 1982), palaeontology (Heaton and Grady 2003; Ramsey et al. 2004; Ward et al. 2003), and glacial geomorphology (Mann 1986).

Late-Glacial Environments

Deglaciation occurred on outer coastal areas earlier than on the inner coast (Barrie and Conway 2002b; Clague 1984; Warner et al. 1982). Retreat in the fjords and mountain valleys was slower than in outer coastal areas as calving of the glacial margin, resulting from eustatic sea level rise, was limited once the ice margin had retreated into these settings (Clague 1984).

Sea Levels

The deglaciation of the northeast Pacific coast occurred in a context of changing global climates and resulted in shifts in the local topography. Following the last glacial maximum, melting of continental glaciers on a global scale resulted in an increase in the volume of water in the earth's oceans, creating a eustatic rise in sea levels (Fairbanks 1989). With wasting of ice, the continental crust rebounded isostatically. In idealized form, glacial isostatic depression occurs as a dish shaped depression sloping towards a centre point of maximum glacial loading (Lowe and Walker 1997). The down-warping

of the crust also occurs in peripheral zone at the margins of the ice front. Beyond this depressed area, the crust may rise upwards like a rim to compensate for laterally displaced subcrustal material. This compensation area is known as the forebulge (Lowe and Walker 1997). As the crust rebounds upon glacial recession the area formerly depressed rises and shrinks in extent. The forebulge also shrinks in area and migrates towards the glaciated region.

Pleistocene-Holocene Transition Shorelines

The interaction of isostatic rebound with eustatic sea-level rise created a complex pattern of relative sea level change on the northern Northwest Coast during the Pleistocene-Holocene transition. Researchers creating relative sea level curves for coastal areas (Barrie and Conway 2002b; Clague et al. 1982; Fedje and Josenhans 2000; Hetherington 2002; James et al. 2002) have found it necessary to create local curves, each of which is specific to a geographic region. These differences are greatest from southwest to northeast, perpendicular to the southeast to northwest trend of the Cordilleran mountain ranges.

In general, immediately following deglaciation, outer coastal areas, such as Haida Gwaii, had sea levels that were significantly lower than today (Figure 8 and Figure 9). The earliest record of late-glacial sea level position comes from the centre of northern Hecate Strait at 37 m below sea level where open marine conditions occurred at 14,380

Figure 8. Schematic cross-section of the north coast of British Columbia illustrating isostatic and eustatic adjustments through time (not to scale).

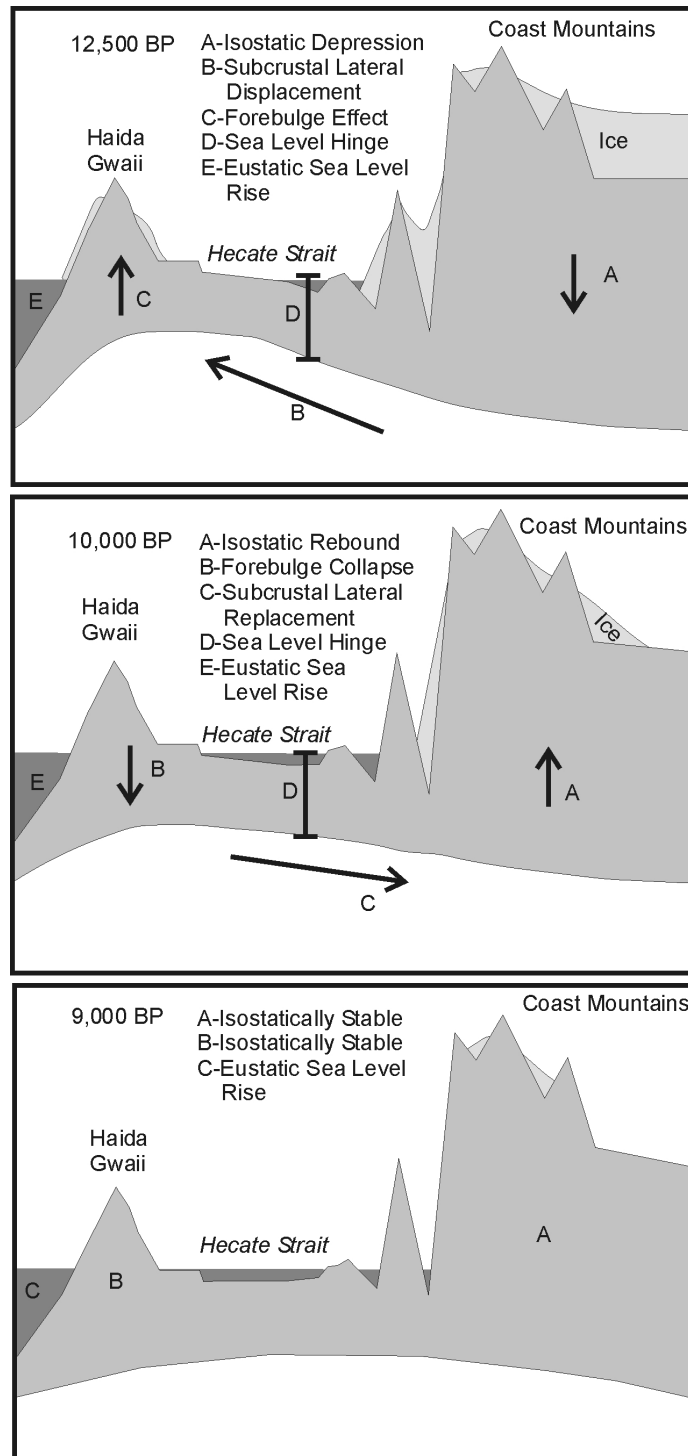
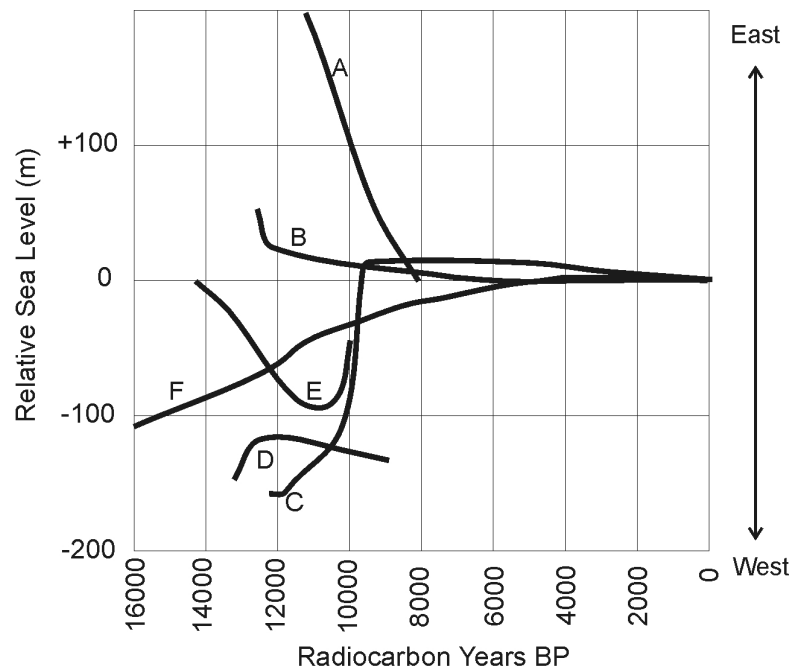


Figure 9. Relative sea level curves for selected areas of north coastal British Columbia.



- A - Kitimat (Clague 1984; Fedje et al. 2005a)
- B - Prince Rupert/Port Simpson (Archer 1998; Clague 1984; Eldridge and Parker 2007; Fedje et al. 2005a)
- C - Southern Haida Gwaii (Fedje et al. 2005a)
- D - Central Hecate Strait (Hetherington 2002)
- E - Northern Hecate Strait (Hetherington 2002)
- F - Global eustatic sea level rise (Fairbanks 1989)

BP (Barrie and Conway 2002a). After this time, relative sea levels began to drop in the same area, reaching their maximum lowering sometime after 13,000 BP and remaining low until 12,400 BP (Barrie and Conway 1999; Josenhans et al. 1997). Data from western Hecate Strait demonstrates that prior to 12,200 BP relative sea level was at least 150 m lower than today (Fedje and Josenhans 2000; Josenhans et al. 1997). The lower relative sea levels of this time were the result of the eastwards migration of a forebulge that uplifted the area relative to the sea and global eustasy (Clague et al. 1982; Fedje et al. 2005b; Hetherington et al. 2002). After this period, with continued deglaciation, isostatic rebound, the collapse of the forebulge (Fedje et al. 2005b), and continued eustatic rise,

sea levels began to transgress until 8,800 BP when they stabilized at 15 m above present-day sea level, forming the early Holocene raised marine features along the eastern shore of Haida Gwaii (Clague et al. 1982; Fedje and Christensen 1999; Fedje et al. 2005b).

Regions closer to the mainland and located within the isostatic depression of the Cordilleran Ice Sheet, had sea levels that were relatively higher than they are today. For example, on the east side of Dixon Entrance, shorelines on the mainland coast were 50 m above present-day sea level 12,600 BP (Fedje et al. 2005b; Hetherington 2002). The earliest dates of marine conditions in the Prince Rupert area at 12,700 BP indicate that sea levels were higher than 11 m (Clague 1984). In southeast Alaska, evidence of raised sea levels is found in many parts of the Alexander Archipelago. On the eastern side of the islands, sea levels appear to have stood about 80-60 m above the present mark ~12,500 BP (Mann 1986).

The area between the outer and inner coast would have been affected much less by abrupt sea level change (Figure 8), resembling a hinge between the isostatically depressed mainland and forebulged outer coast. The Dundas Islands lie near to this hypothesized hinge zone.

In association with isostatic rebound, the earth's crust rose relative to the sea; thus relative sea levels began to regress. Coastal areas that extend inland along fjords and river valleys were isostatically depressed even more and sea levels were as high as 200 m above present-day sea level following deglaciation in places such as Kitimat 10,500 BP (Clague 1984) and the Fraser Valley 12,250 BP (Easterbrook 2003; James et al. 2002). After this time of maximum transgression, the relative sea level in strongly depressed

areas rapidly fell to modern day positions by 9,000-8,000 BP (Clague 1984; James et al. 2002).

Holocene Shoreline Stabilization

After 9,000 BP, major isostatic adjustments associated with the Fraser Glacial event appear to have ended and there was an interval of relative stability when sea level rose to ~15 m on Haida Gwaii (Fedje et al. 2005b). Global eustatic sea level rise appears to have slowed considerably after 8,000 BP (Peltier and Fairbanks 2006). In the vicinity of the north coastal mainland of British Columbia, most sea level curves appear to have reached modern day sea levels by 8,000 BP. Preliminary research with limited data points, undertaken in Prince Rupert Harbour, suggests that sea levels have been higher than -3.5 m since 7,300 BP (Eldridge and Parker 2007).

As a result of interactions between the North American and Pacific plates, this coastal area is tectonically active (Riddihough 1982). In general, this tectonic activity has been working to raise landforms on the west side of Hecate Strait at a rate of 2 mm per year, and to lower them 1 mm on the east side of the strait. This ongoing tectonic activity has been used to explain the dropping of sea levels from their +15 m early Holocene stillstand to their present position on Haida Gwaii (Fedje et al. 2005b).

Late-Glacial Sediments and Geomorphology

The types of sediments and geomorphic features associated with this time of retreating glacial ice and shifting relative sea levels depend on many factors including the speed and type of deglaciation (Barrie and Bornhold 1989; Barrie and Conway 2002b), the amount of sediment supply, and the rates of sea level transgression and regression (Clague 1984). In the Hecate Lowlands region, “glaciers retreated so rapidly across the

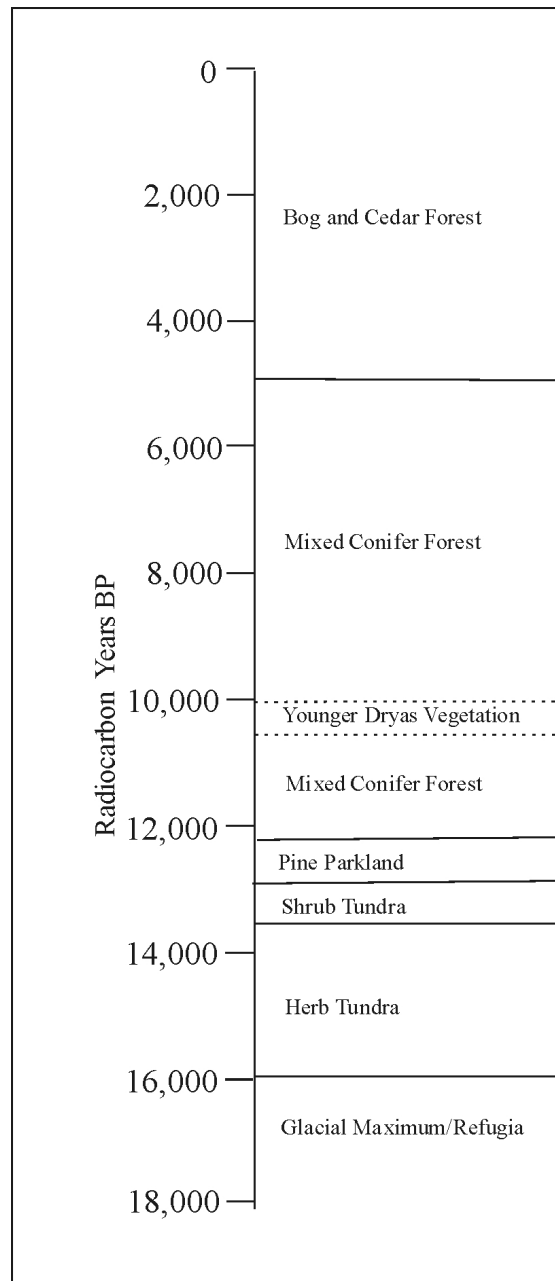
lowland at the close of the Pleistocene that there was not enough time for significant glaciofluvial and glaciomarine sediments to accumulate” (Clague 1984: 45).

In comparison, the region around the southeastern edge of Vancouver Island is characterized by a massive accumulation of glaciomarine and glaciofluvial deposits (Monahan and Levson 2000). In the Puget Sound area, several features associated with deglaciation have been identified and include hummocky topography, outwash deltas, and a series of raised marine terraces (Easterbrook 2003; Kovanen and Slaymaker 2004).

Late-Glacial Vegetation Communities

In association with the highly variable climatic conditions of the late-glacial period, the sequence of plant communities suggests that the northern Northwest Coast underwent rapid climate shifts during the Pleistocene-Holocene transition (Fedje 1993; Hansen and Engstrom; Hebda 1997; Hebda and Whitlock 1997; Hebda et al. 2005; Heusser 1995; Lacourse and Mathewes 2005; Mathewes and Clague 1982; Warner et al. 1982, 1984). The sequence of plant communities on the coast can be characterized by six stages: glacial refugia, herb tundra, shrub tundra, pine parkland, mixed conifer forests, and the rise of boglands and red cedar forests (Figure 10).

Figure 10. Major vegetation community sequences on the northern Northwest Coast as discussed in text (based on Hansen and Engstrom 1996; Hebda et al. 2005; Lacourse et al. 2003; Lacourse and Mathews 2005; Mathews 1989, 1993; Warner et al. 1982, Warner et al. 1984).



Last Glacial Maximum

No plant community sequences are known from the north coast of British Columbia during the Fraser Glacial period between 27,000 and 16,000 BP, but it is

hypothesized that during this period 'glacial refugia' (non-glaciated areas) existed (Heusser 1955, 1989). It has been suggested that landscapes beneath the present day shoreline may have been the location of these refugia (Mathewes 1989). Alternatively, as the majority of glaciers during the late glacial maximum were piedmont lobes bounded by rocky barrens and tundra (Mandryk et al. 2001; Heusser 1995), potential refugia may have been relegated to upland areas such as the palaeo-nunataks of Brooks Peninsula on Vancouver Island (Howes 1997).

Herb Tundra

Palynological and stratigraphic evidence for an early termination of the late glacial maximum on the north coast of British Columbia is found at Cape Ball on the northeastern side of Graham Island (Mathewes 1989; Warner et al. 1982, 1984). Sediments sampled from Cape Ball reveal that vegetation had become established in the area by 16,000-15,500 BP (Warner et al. 1982). Herbaceous plants, Poaceae (grass family), Cyperaceae (sedge family), and mosses characterized this early environment. The sediments are described as mineral rich, suggesting that poorly vegetated soils surrounded the area. *Artemisia* (sagewort) and Poaceae pollen reveal that a dry landscape existed, and Cyperaceae, that local wetlands occurred. This early landscape was tree absent.

Shrub Tundra

Following the early herb tundra-like conditions found at Cape Ball (Warner et al. 1984), there was predominately non-arboreal shrub tundra on the northern Northwest Coast. This type of vegetation community has been identified from samples taken at Pleasant Island in southeast Alaska (Hansen and Engstrom 1996), Langara Island

(Heusser 1995), Cape Ball (Warner et al. 1984), and Westside Pond on Moresby Island (Fedje 1993; Lacourse et al. 2003).

At Pleasant Island in southeast Alaska, pollen Zone PI I, is referred to as a *Salix* (willow) shrub tundra dating as early as 13,760 BP (Hansen and Engstrom 1996). This zone included high percentages of *Salix* (willow), Poaceae, Cyperaceae, Apiaceae (carrot family), and Ericaceae (heath family). Although described as being predominantly non-arboreal, *Pinus contorta* pollen (lodgepole pine) is present making up 20% of the assemblage. The basal sediments for this zone are described as carbonate-rich grey till which grades into a greenish brown gyttja with a 25% organic content.

At Langara Island, the oldest zone (LI-9) was characterized by a coastal shrub tundra community consisting of Poaceae, Cyperaceae, Ericaceae, and *Salix*. An estimated date of 13,000 BP is given for this zone. Between 13,000 and 12,000 BP, an increase of Cyperaceae indicates more humid conditions despite the continuation of a relatively treeless landscape (Heusser 1995). Sediments are limnic peat (Heusser 1955).

At Westside Pond on South Moresby Island, sediments with a basal date of 13,550 BP contain a herb-tundra zone assemblage including Cyperaceae, Poaceae, *Artemisia*, *Heracleum* (cow-parsnip), *Lupinus* (lupin), *Epilobium* (possibly fireweed), among others (Fedje 1993; Lacourse et al. 2003). *Salix*, *Empetrum* (crowberry) and *Lycopodium* (clubmoss) are also important. It is suggested that this zone reflects a cool and moist climate (Lacourse et al. 2003).

According to Lacourse et al. (2003), the Aleutian Islands today have an analogous environment, characterized by cold, wet, and windy conditions and a shrub tundra with high frequencies of Poaceae, Cyperaceae, and Ericaceae pollen. Lacking in permafrost,

the Aleutians are not a true tundra landscape. Despite the characterization of late Pleistocene areas on the north coast of British Columbia as shrub-tundra, there are traces of arboreal pollen including *P. contorta*, *Alnus* (alder), and *T. mertensiana*. It is possible that some of these trees grew in the area, although to a lesser extent than in the following period. Some of this pollen, in particular pine, may be accounted for by long distance transport (Hebda and Allen 1993; Heusser 1995; Lacourse et al. 2003).

Pine Parkland

The shrub-tundra environment changed to a *P. contorta* dominated parkland between 13,000 and 12,000 BP on the north coast of British Columbia. Evidence for this comes from many sources: Pleasant Island (Hansen and Engstrom 1996) and Lily Lake in southeast Alaska (Cwynar 1990), Langara Island (Heusser 1955, 1995), Cape Ball (Mathewes and Clague 1982), Logan Inlet off the east coast of South Morseby Island (Lacourse et al. 2003), Juan Perez Sound off the east coast of South Morseby Island (Fedje and Josenhans 2000; Lacourse et al. 2003), Anthony Island (Hebda et al 2005), Bear Cove on northern Vancouver Island (Hebda 1983), and Brooks Peninsula also on northern Vancouver Island (Hebda 1997) amongst others. On the south coast, pine-parkland was the first pollen zone that appeared and is reflected in cores dating between 14,000 and 13,000 BP (Hebda 1983).

The defining feature of this Pine Parkland period was the predominance of *P. contorta*. There are localized differences in the concentration of pine and the amounts and types of other pollen found. In southeast Alaska, the pine-dominated environment is represented by Zone PI 2 (12,300 –10,600 BP - calibrated) on Pleasant Island (Hansen and Engstrom 1996). It occurred prior to 10,870 BP at Lily Lake on the Chilkat

Peninsula (Cwynar 1990). This landscape was dominated by *P. contorta* and *Alnus* pollen (Hansen and Engstrom 1996). *T. mertensiana* and *Betula* (birch) pollen was also present. There was a decrease in the amount of *Salix* and Ericaceae. There was also a decline in Poaceae and Cyperaceae pollen compared to the previous zones. *Dryopteris* fern spores increased during this zone.

On Haida Gwaii this period was also characterized by a dominance of *P. contorta* pollen. On Langara Island, Heusser (1995) describes this zone (LI-7) as being dominated by *P. contorta* and *Alnus* with light demanding fern species (Filicinae) suggesting a relatively open setting existed, characteristic of pine parklands. At Cape Ball, zone CB-2 was characterized by humified peat deposits with a landscape dominated by *P. contorta*, ferns, *Equisetum* (horsetail), and Cyperaceae (Mathewes and Clague 1982; Warner et al. 1982). At Logan Inlet, the pine dominant zone occurs in basal sediments dating to 12,000 BP (Lacourse et al. 2003). Other taxa present during this period were *Polypodium* (fern), *Adiantum* (maidenhair fern), monolete undifferentiated fern spores (probably *Athyrium* and *Dryopteris*), Cyperaceae, and *Alnus*. A pine stump dating to 12,240 BP was excavated from 145 m below the sea level in Juan Perez Sound off the east coast of Moresby Island (Fedje and Josenhans 2000). Pollen found in peat deposits associated with the pine stump indicate a *P. contorta* dominated landscape that also included *T. mertensiana*, *Salix*, *Empetrum*, *Heracleum*, and fern spores (Lacourse et al. 2003).

Basal deposits from Bear Cove bog on northeastern Vancouver Island and Brooks Peninsula on northwestern Vancouver Island have evidence of a pine zone (Hebda 1983, 1997). The sequence at Bear Cove suggests that a pine zone immediately followed the glacial maximum period, unlike areas to the north where shrub or herb tundras were

associated with post-late glacial maximum basal deposits. Bear Cove I dates between 14,000 and 11,500 BP and was pine-dominated. Later, *Alnus* appeared and increased in quantity. Likewise, the earliest fossil evidence of plant communities in the Brooks Peninsula area suggest a late-glacial pine zone characterized by *T. mertensiana*, Poaceae, Cyperaceae, *Artemisia*, Asteraceae (aster), and *Empetrum*.

The dominance of pine during this period is attributed to the lack of competing species, and the ability of this tree to rapidly propagate in areas with poor soils (Heusser 1995). *P. contorta* may have survived in coastal refugia (Hebda 1983). The expansion of *P. contorta* during this period may be attributable to an increase in temperature prior to an increase of moisture signalled by the arrival of *Alnus* (Hansen and Engstrom 1996).

Mixed Conifer Forest

Following the open *P. contorta* dominated parklands, other conifer species began to establish and forest canopies became denser (Hebda et al. 2005). Evidence of the establishment of conifers during this period comes from sites on Haida Gwaii where *Picea* and *T. mertensiana* increased between 12,000 and 11,000 BP (Hebda et al. 2005; Lacourse and Mathewes 2005) and northern Vancouver Island (Hebda 1983, 1997). This rise of conifers other than *P. contorta* does not appear to have occurred at Pleasant Island in southeast Alaska (Hansen and Engstrom 1996).

From sediments sampled on Anthony Island (southern Haida Gwaii) *Picea* outpaced *P. contorta* beginning 11,700 BP (Hebda et al. 2005). *Alnus* and ferns were also important during this period. At other sites on southern Haida Gwaii, the increase in *Picea* was complemented by an increase in *T. mertensiana* (Fedje 1993; Lacourse and Mathewes 2005)

Younger Dryas Vegetation

In southeast Alaska and on Haida Gwaii, the establishment of conifers was followed by a period of cooler relative temperatures referred to as the Younger Dryas (Mathewes 1993). The Younger Dryas cooling occurred in some areas with an increased occurrence of *T. mertensiana* and in other areas by a reversion to shrub-tundra environments (Mathewes 1993).

In southeast Alaska, in zone PI 3 from Pleasant Island a “radical” change in vegetation is noted between 10,600 and 9,900 BP (Hansen and Engstrom 1996). There was a large decline in the amount of pine and alder that coincided with an increase in *Sanguisorba* (burnet), *Artemisia*, Cyperaceae, Poaceae, and other herbs. A herb tundra replaced the pine parklands of the previous period. The climate during this period was likely drier and colder than in the previous zone (Hansen and Engstrom 1996).

In cores from Haida Gwaii, an increase in *T. mertensiana* and *Alnus* signals the onset of Younger Dryas cooling (Heusser 1995; Fedje 1993; Mathewes 1993). In some areas *Picea* (spruce) increased (Fedje 1993; Heusser 1995). *Picea* cones dating to this period recovered from Cape Ball are interpreted as white/Sitka spruce hybrids (Warner and Chmielewski 1987).

Mixed Conifer Forest during the Early Holocene Amelioration

The period that followed the Younger Dryas was warmer and dryer and characterized by the continued expansion of coastal forests similar to those of the present day (Hebda and Whitlock 1997; Mathewes 1993). This period of climatic warming brought about assemblages dominated by *Picea sitchensis* (Sitka spruce) and *Tsuga heterophylla* (western hemlock) at sites in southeast Alaska and Haida Gwaii (Cwynar

1990; Fedje 1993; Hansen and Engstrom 1996; Heusser 1995; Warner 1984). Prior to the establishment of spruce and western hemlock on Langara Island and southeast Alaska, an *Alnus* and fern shrubland zone existed (Cwynar 1990; Hansen and Engstrom 1996; Heusser 1995). By 7,000 BP, all areas were dominated by coastal forests. Wetland areas occurred as indicated by the presence of *Lysichiton* (skunk cabbage), in particular in the Holocene sediment core from a woodland bog near Prince Rupert (Banner et al. 1983), Langara Island (Heusser 1995), and Pleasant Island (Hansen and Engstrom 1996). During this period there was also a decline in herbaceous plants and pine (Hansen and Engstrom 1996).

Bogs and Cedar Forest

In the early to mid Holocene two changes are notable in pollen core assemblages. The first was the appearance of scrub woodlands and boglands (muskeg) beginning in the Prince Rupert area around 8,000 BP (Banner et al. 1983; Turunen and Turunen 2003). Associated with this change was a decrease in the amount of *Picea* and *Lysichiton* on the landscape combined with increased *P. contorta*, Ericaceae, and *Sphagnum* moss (Banner et al. 1983; Turunen and Turunen 2003). The onset of bog ecosystems was likely the result of a period of cooling and moistening (Hebda and Whitlock 1997), but also due to successional factors, primarily soil development, increased acidity, and overall paludification (Banner et al. 1983; Hansen and Engstrom 1996). The second change in more southerly north coast settings was the marked increase in Cupressaceae (cypress family, mostly red cedar) after 5,000 BP (Hebda and Mathewes 1984; Lacourse and Mathewes 2005). The increase in Cupressaceae also signals an increase in relative humidity and possibly a change in soil moisture and acidity (Hebda and Whitlock 1997).

Summary

The sequence of plant communities during the Pleistocene-Holocene transition reveals a series of rapidly changing environmental conditions. Later Holocene environmental conditions were more stable. However, the early Holocene appears to have been warmer and drier than conditions in the late Holocene. Early human populations on the coast could have drawn on a number of different plant species for subsistence purposes (Lacourse and Mathewes 2005). Many of these plants continued to be available and used into late Holocene times. Prior to 11,000 BP, however, with the exception of pine and alder, arboreal species were initially lacking or infrequent, and red cedar was not abundant in the region until the late Holocene (Hebda and Mathewes 1984).

Palaeontology

The climatic changes that occurred on the northern Northwest Coast resulted in changes in fauna. Many of the species currently found became established in the late-glacial period between 12,000 and 10,000 BP (Wigen 2005). Most of what is known about fauna dating to the late Pleistocene has been found in karst cave contexts in southeast Alaska and Haida Gwaii. Holocene records come from archaeological sites and caves.

Late Glacial Maximum

While there are changes in the types of animals found along the north British Columbia and southeast Alaska coasts, the large-scale extinctions of Pleistocene megafauna found elsewhere in the Americas (Meltzer and Mead 1985) are not well recorded, with the exception of the most southerly areas (e.g., Puget Sound, Vancouver

Island, and the Fraser Valley). Typical examples of extinct Pleistocene megafauna do not appear to have moved into north coastal regions following the last glacial maximum. Exceptions to this may be fossil wood bison (*Bison bison athabascae*) remains found in the vicinity of Kitimat (Smith 1977) and a report of a proboscidian in the vicinity of Sandspit on Haida Gwaii (Dalzell 1968). Both finds are undated and may predate the last glacial maximum.

The biostratigraphy of faunal remains from Prince of Wales Island in the southern Alexander Archipelago is continuous throughout the Fraser glaciation with the exception of the period spanning 17,100-14,500 BP which is interpreted as evidence for the timing of the late glacial maximum when the cave was possibly overridden by ice (Heaton and Grady 2003). Species found on either side of this hiatus include *Phoca vitulina* (harbour seal), *Phoca hispida*, (ringed seal), *Vulpes vulpes* (red fox), *Alopex lagopus* (arctic fox), and *Eumetopias jubatus* (Stellar sea lion). The presence of these species suggests conditions similar to those found along the coasts of the Bering Sea and Arctic Ocean today, which support sea-ice adapted fauna (Heaton and Grady 2003). Forty-four bird taxa are known from this same sea-ice period and were likely brought into the cave by *A. lagopus* (Heaton and Grady 2003). Combined, the late Pleistocene fauna from Southeast Alaska cave contexts reveals that sea ice conditions were present in the region from 24,150 BP through 13,690 BP, with the notable hiatus of all species between 17,100 and 14,500 BP (Heaton and Grady 2003).

Late-Glacial Fauna

With the disappearance of sea-ice fauna from southeast Alaska 13,690 BP, the establishment of late-glacial fauna began. Evidence of this fauna is primarily from karst

caves in southeast Alaska and Haida Gwaii (Heaton and Grady 2003; Ramsey et al. 2004; Wigen 2005). Most notable in this period is the reappearance of bears. On Haida Gwaii, the earliest post-glacial evidence is a single *Ursus arctos* (brown bear) bone that dates to 14,500 BP (Ramsey et al. 2004). This early specimen from Haida Gwaii is a single sample and all other dates on *U. arctos* from Haida Gwaii post-date 12,205 BP. *U. arctos* reappears in the sequence in southeast Alaska around 12,295 BP (Heaton and Grady 2003). Following the glacial maximum, *U. americanus* (black bear), first appears 11,280 BP on Haida Gwaii and 11,565 BP in southeast Alaska. The early reappearance of brown bears on the northern Northwest Coast has been suggested by some researchers to be evidence that a glacial refugium extensive enough to support these large omnivores existed somewhere in the vicinity (Heaton and Grady 2003; Ramsey et al. 2004).

Many other taxa appear in late-glacial caves after 12,000 BP. Species and the first dates of their appearance include: *Rangifer tarandus* (caribou) 11,560 BP (Heaton and Grady 2003) and *Odocoileus hemionus* (Mule or Sitka black-tailed deer) 11,265 BP (Fedje et al. 2007). During the period between 12,000 and 9,000 BP numerous small mammals are recorded at these sites including *Canis familiaris* (domestic dog) (Wigen 2005; Fedje et al. 2007). Fish remains from Gaadu Din cave include Salmonidae (salmon) remains in levels predating 11,000 BP, and continuing through to 10,000 BP (Fedje et al. 2007). Other fish remains post date 11,000 BP but include *Salvelinus malma malma* (Dolly Varden char) and *Oncorhynchus mykiss* (steelhead/rainbow trout). Additionally, some small marine species have been found on the surface in this cave, appear to post-date 10,000 BP (Wigen 2005), and are likely the result of rising sea levels bringing these marine species and their predators closer to the cave.

Sediment cliff sections and cores dating from the late-glacial period provide evidence that other maritime species appear to have moved into north coastal British Columbia and southeast Alaska soon after glacial retreat. Molluscs from samples in the Hecate Strait region are first recorded at 14,180 BP (Hetherington et al. 2004). Dated specimens include *Cassidula* species (14,180 BP), *Macoma nasuta* (bent-nosed clam) (13,220 BP), and *Tresus nuttallii* (Pacific gaper clam) (12,650 BP).

Evidence of early late-glacial animal communities reveals that habitats able to support large mammals, including humans, directly follow deglaciation. In some places, species have become locally extirpated, such as *U. arctos* and *Odocoileus hemionus sitkensis* (Sitka black-tailed deer) on Haida Gwaii (deer having been reintroduced in the 20th Century). Regardless of localized extinctions, most species found between 13,500 and 9,000 BP (Wigen 2005) continued to thrive despite shifts in climatic conditions, suggesting that the models of climate change and human over-hunting that have been used to explain Pleistocene-mega faunal extinction elsewhere in the Americas (Grayson and Meltzer 2002) do not necessarily apply on the northern Northwest Coast. The earliest people on the Northwest Coast encountered fauna that their descendents drew upon for subsistence over the millennia that followed.

Holocene fauna

The faunal record following 10,000 BP is similar in many respects to the early-late-glacial fauna described above. Faunal remains from the archaeological site at Kilgii Gwaay in southernmost Haida Gwaii (Fedje et al. 2001; Fedje et al. 2005c; Wigen 2005) provide a unique perspective on the types of fauna used by human populations in the early Holocene period. Mammal remains include *U. americanus* (black bear), *Phoca*

vitulina (harbour seal), *Enhydra lutris* (sea otter), *Lontra canadensis* (river otter), *Eumetopias jubatus* (northern sea lion). Twenty taxa of birds were recovered, including *Ptychoramphus aleuticus* (Cassin's auklet), *Phoebastria albatrus* (short-tailed albatross), Alcidae (alcid), and *Phalacrocorax auritus* (Double-crested cormorant). Of the 13 taxa of fish, *Sebastes* species (rockfish), *Squalus acanthius* (dogfish), *Ophiodon elongatus* (lingcod), *Scorpaenichthys marmoratus* (cabezon), and *Hexagrammos* species (greenling) were found to be the most abundant. All of the fauna found at Kilgii Gwaay are present in the region today. Faunal material from other early Holocene archaeological contexts on the northern Northwest Coast, including Cohoe Creek on Graham Island (Christensen and Stafford 2005) and Chuck Lake in southeast Alaska (Ackerman 1996b), contain faunal remains reflecting local biogeographic conditions of outer coastal areas similar to those found today. At least one recently extirpated species is among the material collected from Cohoe Creek: Dawson Caribou (*Rangifer tarandus dawsoni*), which died out on Haida Gwaii between 1910 AD and 1920 AD (Christensen and Stafford 2005; Wigen 2005). Later Holocene archaeological contexts with faunal remains are most abundant in Prince Rupert Harbour. The fauna from these sites is characteristic of the terrestrial, marine, anadromous, and riverine species found in the vicinity today (Stewart and Stewart 2001). Outer coastal archaeological sites, such as those on Kunghit Island, similarly reflect local biogeographic conditions (Acheson 1998).

In general, environmental conditions on the north coast of British Columbia have supported faunal communities since at least the late-glacial era. Many of the species which occur in the region today have been found in paleontological and archaeological contexts dating from 11,000 BP.

Conclusion

Palaeo-environmental research on the northeast Pacific coast reveals that the last glacial maximum was relatively short, 2,500 years, based on a hiatus of faunal material, on Prince of Wales Island (Heaton and Grady 2003), and possibly shorter on Haida Gwaii with the earliest dates of ice-free conditions at Cape Ball (Warner et al 1982; Warner et al. 1984). Glacial retreat appears to have occurred in outer coastal areas between 16,000 and 14,500 BP and sea-ice conditions seem to have abated between 14,000 and 13,000 BP. The early presence of plant and animal communities reveals that the region was not barren during early late-glacial times and many biotic communities were supported as were large mammals. Many researchers have hypothesized that these types of conditions made the region available for human migrants moving from northeast Asia into the Americas (Fedje et al. 2004a; Fladmark 1979; Hetherington 2002). However, there has been a lack of empirically-based tests of hypothesis (Fedje et al. 2004a).

Geological and geomorphic evidence reveals that, if they existed, coastal archaeological sites dating to the late Pleistocene and Early Holocene would be located near relict shoreline features either above or below present-day sea level. Pollen evidence demonstrates that the late-glacial transition period was dynamic and characterized by major shifts in vegetation communities. The Holocene vegetation record points to a more stable development of plant communities. Paleontological research reveals that marine and terrestrial species thrived in the region very soon after glacial retreat. In the north part of the study area, the earliest late-glacial mammalian faunal assemblages have similarities to arctic animal communities. On Haida Gwaii, the early occurrence of bears suggests the presence of coastal refugia able to support large

mammals. These patterns reveal that extensive habitats capable of supporting human communities were available 14,500-13,000 BP. After 11,000 BP, paleontological remains reveal that fauna similar to those found on the Northwest Coast today were becoming established. In this manner, the faunal subsistence base of Northwest Coast culture, including salmon, has been available since the late Pleistocene.

This chapter presents a review of late Pleistocene and early Holocene palaeo-environmental research on the northern Northwest Coast. Key elements of the material considered include the timing of the last glacial maximum and glacial retreat, the potential for glacial refugia, sea level change, the dynamic sequence of plant communities, and the establishment of animal communities.

Chapter IV – Archaeological Context

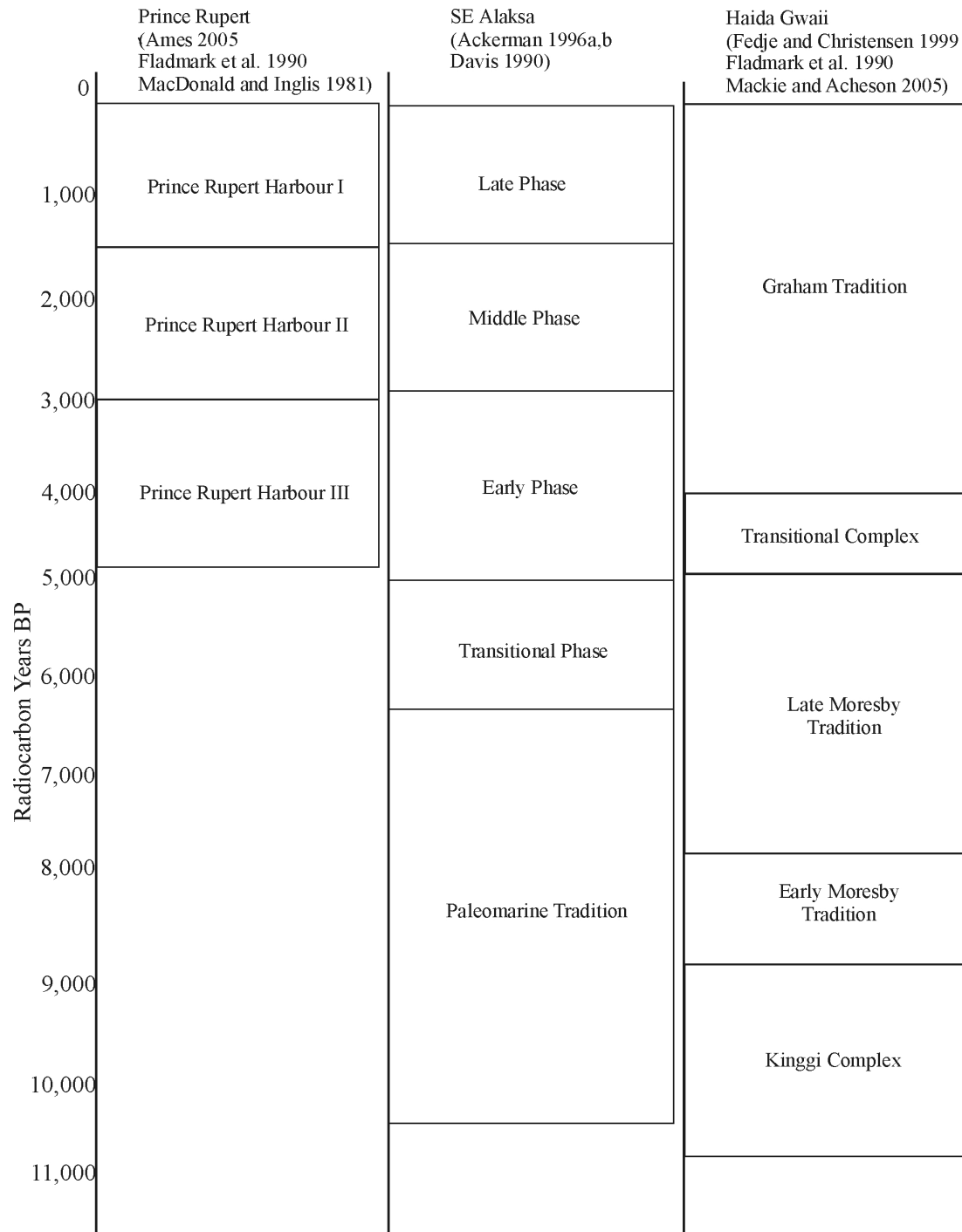
Introduction

Sea level change has been recognized as a factor affecting archaeological site locations on the Northwest Coast since archaeologists began working in the area in the late 1800s (Smith 1898). The primary goal of this chapter is to review the relationship of archaeological site locations to sea level. An overview of the types of materials and interpretations associated with northern Northwest Coast archaeological sites dating to times of shoreline change, as well as times of shoreline stability, is also presented. These topics situate this dissertation within the context of northern Northwest Coast archaeological research. For convenience, this chapter approaches the archaeological record of three different broad time periods: the late Pleistocene (>10,000 BP), the early Holocene (10,000–5,000 BP), and the late Holocene (5,000-200 BP). Southeast Alaska, Haida Gwaii, and Prince Rupert Harbour have regional cultural historical sequences with occupation beginning 10,500 BP (Figure 11).

Peopling of the Northwest Coast

The Northwest Coast remains an intriguing geographic region in the study of the peopling of the Americas. Palaeo-environmental evidence suggests that the coastal area was deglaciated early enough to have been a migration route along which the first, and/or subsequent, groups of people could have moved from Asia into the Americas (Fladmark 1979). There is, however, a lack of direct archaeological evidence for the use of this area early enough (pre-12,500 BP) to confirm it as a corridor for the initial peopling of the Americas.

Figure 11. Culture-history chart for the northern Northwest Coast.



Related genetic and linguistic attributes between the Indigenous peoples of the Americas and those of northeastern Asia suggest that the earliest Americans came from

northeast Asia (e.g., Boas 1912b; Nichols 2002; Schurr 2004). These assertions are based more on comparative linguistics and the genetic relationships of recent populations than on archaeological evidence. Archaeologists have approached the northeastern Asian origins of the peoples of the Americas as a testable hypothesis and have sought to find early archaeological sites in the Americas and northeast Asia for the express purpose of demonstrating how, where, and when such migrations occurred. A vast amount of research, modeling, and reporting in this field has culminated recently in the publication of numerous syntheses including amongst others: Shutler (1983), Carlson and Dalla Bona (1996), West (1996), Bonnicksen and Turnmire (1999), Dixon (1999), Bever (2001), and Madsen (2004a).

During and immediately following the last glacial maximum, global sea levels were much lower than today and northeast Asia and northwest North America were connected by the Bering land bridge. The emergence of this landscape facilitated the hypothesized migration route of early settlers (Hopkins 1996). With the earliest known sites in the Americas dating to at least 12,500–12,000 BP (Adovasio and Pedler 2004; Bever 2001; Cook 1927; Dillehay 1997; Haynes and Agogino 1960; Willig and Aikens 1988), archaeologists have created models of migration around the perimeters of the massive continental ice sheets that would have been an impediment to groups moving from the Beringian land bridge into more southerly parts of the Americas (Fladmark 1979; Johnston 1933; Madsen 2004b; Mandryk et al. 2001). In general, there are currently four hypotheses as to how this process of peopling occurred (Meltzer 2004: 546):

- 1) A single migration in pre-last glacial maximum times (before 18,000 BP),

- 2) Multiple migrations, the earliest of which is pre-last glacial maximum (before 18,000 BP),
- 3) A single migration in post-last glacial maximum times (after 15,000 BP), and
- 4) Multiple migrations in post-last glacial maximum time (after 15,000 BP).

In consideration of the first two hypotheses, no archaeological sites with general acceptance in the research community predate the last glacial maximum (Grayson 2004; Meltzer 2004). To date, the earliest widely-accepted archaeological sites are located in Alaska, the continental United States, and South America; all dated to between 12,500 and 11,500 BP (Grayson 2004; Kelly 2003). In particular, the Monte Verde site in Chile at 12,500 BP (Dillehay 1997), sites in Alaska beginning at 12,360 BP (Largent 2004), and the Clovis Complex sites in the region south of the continental ice sheets, at 11,300 BP (Haynes 1992) have been assessed using a set of research standards. Dixon (1999) summarizes these standards that have been employed and expanded upon to demonstrate Pleistocene archaeological sites in the Americas:

- 1) artifacts must be clearly human made,
- 2) the recovered material must be in clear stratigraphic context,
- 3) radiocarbon dates must be reliable and stratigraphically consistent, and
- 4) palaeo-environmental data must be consistent with the age of the site.

In lieu of these criteria, directly dated human remains are the most reliable and valid form of evidence. While there are several archaeological sites that predate Monte Verde, and others still that predate the last major glacial event, they have not met the criteria outlined above, and are not generally accepted by the archaeological community (Dixon 1999).

The hypothesis that the oldest firmly dated archaeological sites in the Americas immediately follow the last glacial maximum has resulted in the prediction that one of two routes was used by the first migrants to the Americas: the ice-free corridor which opened up between the Cordilleran and Laurentide Ice Sheets (e.g., Johnston 1933; West 1996) or the coastal migration route along the westerly margins of the Cordilleran Ice Sheet (e.g., Dixon 1999; Erlandson 2002; Fladmark 1979; Mandryk et al. 2001).

Palaeo-environmental evidence suggests that the ice-free corridor was not open until 11,500 BP (Burns 1996; Jackson et al. 1997; Mandryk et al. 2001), not early enough to account for the human presence at Monte Verde (Dillehay 1997) or other possible pre-Clovis sites (Adovasio and Pedler 2004). In light of these findings, archaeologists have begun to seriously consider the coastal migration route (Dixon 1999; Erlandson 2002; Fedje et al. 2004a; Mandryk et al. 2001), as well as the possibility of a pre-late glacial maximum migration to the Americas (Madsen 2004b). Key to the idea of the coastal migration route is the assertion that early inhabitants in the area were maritime resource adapted, and used watercraft (Dixon 1999; Erlandson 2002; Fedje et al. 2004a).

Despite the models of migration routes and times, archaeological sites with general acceptance and which are old enough to account for Monte Verde and Clovis populations have not been found in the ice-free corridor, along the Northwest Coast, or pre-dating the last glacial maximum. Similarly, the oldest archaeological sites in western Beringia (northeastern Siberia) post-date archaeological sites in the Americas, although further to the west (central and southern Siberia), some pre-late glacial maximum sites have been located and dated (Goebel 1999, 2004; Goebel et al. 2003).

Late Pleistocene Archaeological Sites on the Northwest Coast (>10,000 BP)

There have been few archaeological projects on the Northwest Coast oriented at discovering late Pleistocene archaeological sites (Figure 12). It is generally accepted that much of the shoreline was lower than at present (Fedje et al. 2004a; Fladmark 1979). For this reason, archaeological research oriented at discovering late Pleistocene archaeological sites on the northern Northwest Coast has focussed on submerged terrestrial features (Fedje and Josenhans 2000) and inland areas that would have attracted inhabitants, such as cave sites in southeast Alaska and Haida Gwaii (Dixon et al. 1997; Fedje et al. 2004b). Although these projects located late Pleistocene archaeological sites, they have been hampered by logistical difficulties such as working at significant depths underwater or by ephemeral evidence of late Pleistocene cultural use.

Three archaeological sites on the northern Northwest Coast have archaeological deposits that clearly date prior to 10,000 BP: On-Your-Knees Cave on Prince of Wales Island (Dixon et al. 1997), and K1 and Gaadu Din caves on Haida Gwaii (Fedje et al. 2004b). All of these cave sites have evidence of use during this same period by bears. These cave sites are inland of the present shoreline, and at the time of occupation, when sea levels were lower, would have been considerably further still from the shoreline.

Figure 12. Locations of late Pleistocene archaeological sites on the western coast of North America.

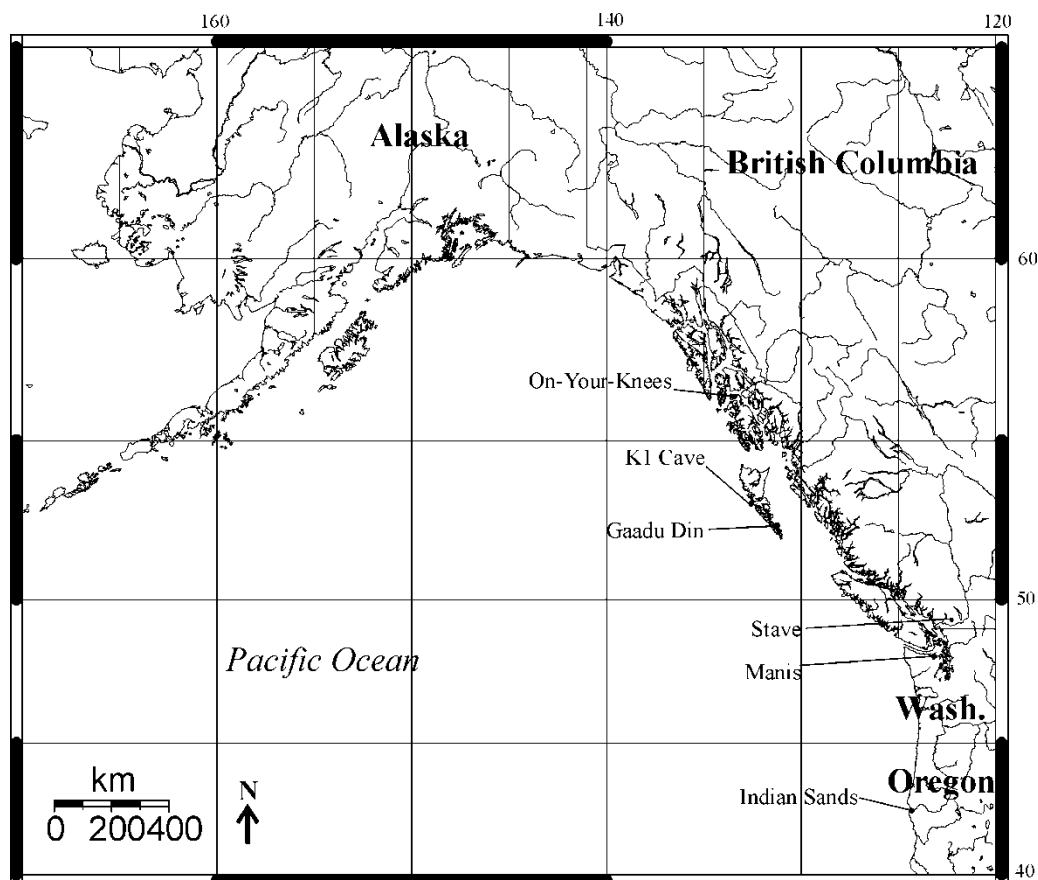


Table 5. List of late Pleistocene archaeological sites and elevations on the Northwest Coast of North America.

SITE AND LOCATION	CITATION	EARLIEST EVIDENCE OF HUMAN OCCUPATION	SETTING (RELATIVE TO MODERN SHORE)	TECHNOLOGY
On-Your-Knees – southeast Alaska	Dixon et al. (1997); Dixon (1999)	10,300 BP (ground bear bone)	Cave (135 m asl, 0.5 km inland)	Bear/human interaction
K1 Cave – Haida Gwaii	Fedje et al. (2004b)	10,900-10,500 BP	Cave (40 m asl, ~1 km inland)	Biface, bear hunting
Gaadu Din – Haida Gwaii	Fedje et al. (2007)	10,500-10,000 BP	Cave (45 m asl, 0.3-0.4 km inland)	Biface, bone tool, bear hunting
Stave Lake – SW British Columbia	McLaren et al. (2007)	10,150	Lake (72-80 m asl, 47 km inland)	Biface preform and biface reduction flakes
Manis Mastodon – Olympic Peninsula	Gustafson et al. (1979)	12,000 BP	Bog (165 m asl, ~5 km inland)	Possible bone point and stone spall associated with mastodon bones
Indian Sands – Oregon Coast	Davis et al. (2004)	10,430 BP	Dune (30 m asl, ~0.25 km)	Flake and retouched tools

Investigations of drowned shorelines on the west side of Hecate Strait, near Juan Perez Sound, resulted in the discovery of a single flake from fluvial gravels situated 50 m below water depth (Fedje et al. 2005a). Sea levels were at this elevation 10,000 BP and it is believed that this artifact dates to this time period (Fedje and Josenhans 2000). No other definite cultural material was found during this testing.

On the southern Northwest Coast, archaeological sites dating to the late Pleistocene period have been reported at Sequim in Washington State (Gustafson et al 1979), Stave Lake in the Fraser Valley (McLaren et al. 2007), and at Indian Sands in Oregon State (Davis et al. 2004). Recently, the date from Indian Sands has been questioned (Erlandson and Moss 2008).

Technology

The Manis Mastodon site is the oldest dated archaeological site on the Northwest Coast (Gustafson et al. 1979). It features *Mammot americanum* (mastodon) bones excavated from beneath peat bog deposits. One of the *M. americanum* ribs has a bone point embedded in it around which the rib has healed. One flaked cobble spall was also found in association with the bones. Radiocarbon samples on associated materials returned dates of 12,000 and 11,850 BP. Some archaeologists have questioned whether the bone point is of human manufacture (Carlson 1990; Dixon 1999; Grayson and Meltzer 2002). The association of the cobble spall with the *M. americanum* remains is unclearly reported and the illustration of the spall is poor (Grayson and Meltzer 2002). Overall, the site is poorly reported, the nature of the site stratigraphy in relation to the bones and radiocarbon dates is uncertain (Dixon 1999), and it has not been adequately demonstrated that the tools are definitely made by humans.

With the exception of the Manis site, the earliest archaeological assemblages in the Northwest Coast culture area are collectively referred to as the Pebble Tool tradition (Carlson 1996c) and represent a marine-adapted people whose technological assemblage included lithics such as foliate-shaped chipped stone bifaces and an associated flake and cobble tool industry. Some researchers refer to the Pebble Tool tradition as the Old Cordilleran culture and suggest it represents interior palaeo-Indian big game hunters that moved into coastal areas (Coupland 1998; Matson and Coupland 1995). On Haida Gwaii this period is related to the Kinggi complex (Fedje and Mackie 2005). The foundations of this tradition appear in the late Pleistocene but it continues into the early Holocene.

Unlike mid and late Holocene assemblages on Haida Gwaii, late Pleistocene archaeological sites have foliate bifaces (Figure 13). At K1 cave on Haida Gwaii, two large foliate-shaped projectile points with basal lateral grinding, referred to as Taan spear points, have been found dating to 10,500 BP (Fedje et al. 2008). Two teardrop-like and foliate-shaped bifaces, referred to as Xil points, a flake tool, and a bone point found at Gaadu Din cave date between 10,500 and 10,000 BP (Fedje et al. 2007; Fedje et al. 2008). A single split and ground bear bone (possible a soft hammer flaker) from On-Your-Knees-Cave dating to 10,300 BP (Dixon 1999), places this site in the late Pleistocene.

With the possible exception of the Manis site, the early archaeological technologies of the Northwest Coast are distinct from other North American Pleistocene-Holocene transition assemblages. While the famed palaeo-Indian traditions of the Plains (e.g., Clovis, Folsom, Plano) seem to have permeated throughout much of the North

Figure 13. Chart illustrating the types of artifacts found on Haida Gwaii through time.

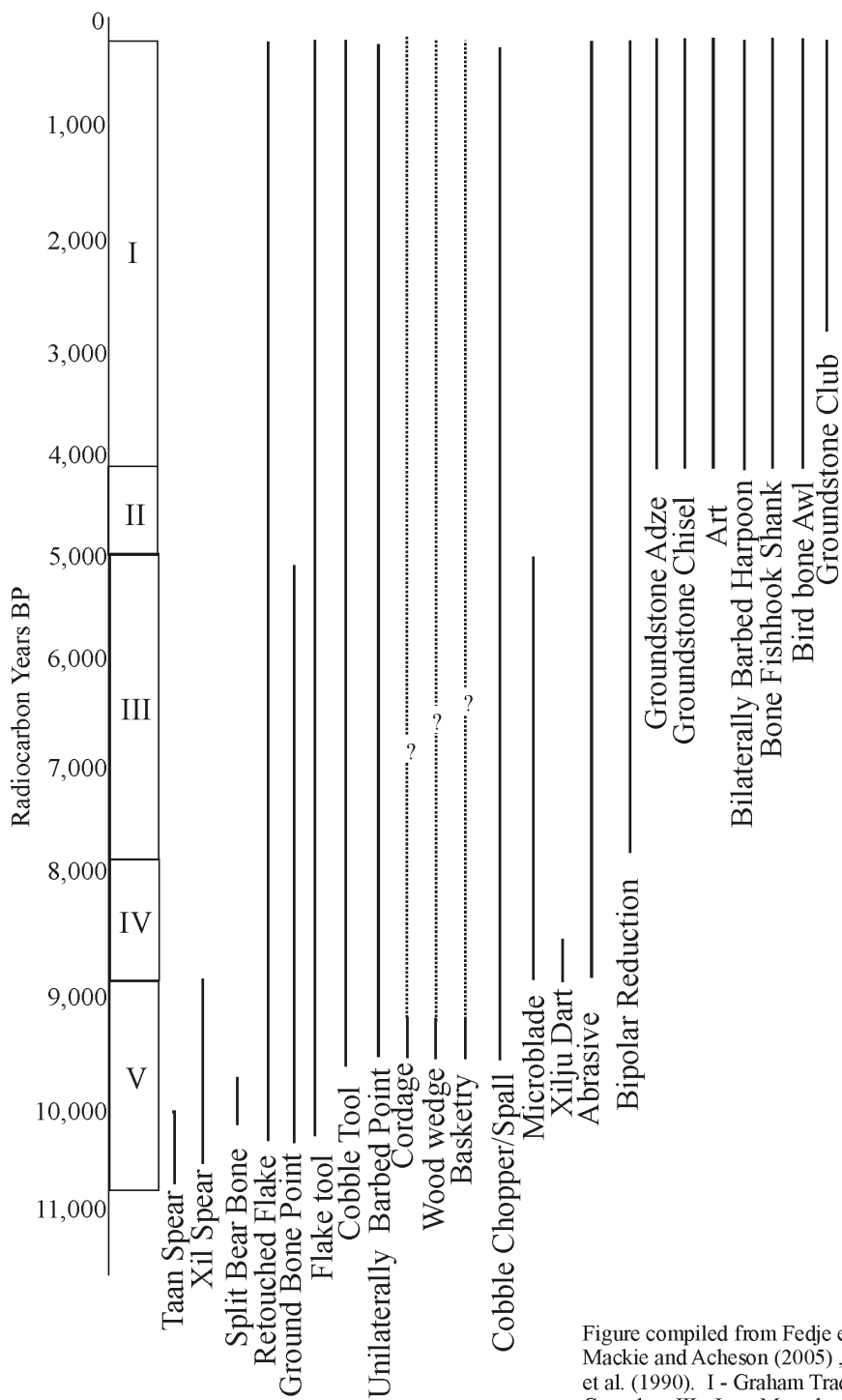


Figure compiled from Fedje et al. (2007b), Mackie and Acheson (2005), Fladmark et al. (1990). I - Graham Tradition, II - Transitional Complex, III - Late Moresby Tradition, IV - Early Moresby Tradition, V - Kingi Complex

American continent (Frison 1978), including the interior of British Columbia and Alaska (Bever 2001; Fladmark 1996; Wilson 1996), early archaeological sites on the Northwest Coast appear to be more related technologically to palaeolithic Siberian and Beringian traditions (Ackerman 1996a; C. Carlson 2003; R. Carlson 1996c).

Subsistence

Overall the archaeological evidence of the late Pleistocene period (>10,000 BP) on the Northwest Coast is scant and subsistence information is limited. Most of the sites from this period are from inland, as opposed to shoreline, contexts (Table 5) and reveal subsistence activities including bear hunting on the north coast (McLaren et al. 2005) and Mastodon hunting on the south coast (Gustafson et al. 1979). While there is no direct evidence of a maritime adaptation in the archaeological deposits dating to this time period, it can be inferred from the location of the cave sites on coastal islands that people were at the very least using watercraft. Furthermore, archaeological sites dating just slightly later than 10,000 BP reveal that inhabitants of shoreline habitation sites had well rounded marine subsistence: Kilgii Gwaay (9,400 BP) and Richardson Island (9,300 BP) (Fedje et al. 2001; Steffen 2006).

Early sites to the south of Oregon and along the Pacific margin of the Americas, have revealed evidence of maritime adaptation and early occupation with technological complexes that differ from those found in much of continental North America (Fedje et al. 2004a). Several of these sites predate the earliest known archaeological deposits on the Northwest Coast. Some examples include: Daisy Cave on San Miguel Island, California (10,400 BP) (Erlandson 1994; Erlandson et al. 1999), Paiján culture sites on North Coastal Peru (10,800 BP) (Dillehay et al. 2003), and Quebrada Jaguay, Peru

(11,100 BP) (Sandweiss et al. 1998). This evidence for early human occupation of the Americas along the Pacific margin, combined with evidence for maritime adaptation, suggests the possibility of an early late-glacial peopling of the Americas via the coastal migration route (Dixon 1999; Erlandson 2002; Fedje et al. 2004a; Lavallée 2003).

Human Remains

No human bones dating before 10,000 BP have been reported on the Northwest Coast. To the south of the Northwest Coast, on the Channel Islands of California, the bones of ‘Arlington Springs woman’ returned radiocarbon dates between 11,000 BP and 10,000 BP (Erlandson 2007; Rick et al. 2005). Apparently, these remains have been reassessed and are now thought to be from a man (Erlandson et al. 2008). Isotopic assays have not been undertaken to determine the marine contribution of the diet of this individual. These findings are significant as they reveal that “maritime Paleoindians used watercraft to settle the Northern Channel Islands by the terminal Pleistocene” (Rick et al. 2005: 177).

The Early Holocene Archaeological Record (10,000-5,000 BP)

Unlike the late Pleistocene archaeological record, several archaeological sites have been located on early Holocene palaeo-shorelines (Table 6 and Figure 14). Indeed, most of these early archaeological sites on the Northwest Coast are located on relict marine shorelines, although some are associated with inland use areas. A considerable proportion are located on Haida Gwaii, one of the few places on the Northwest Coast where survey projects have actively focussed on investigating raised marine features looking for archaeological remains (Fedje and Christensen 1999; Fedje et al. 2005b; Stafford and Christensen 2000).

One hundred and eleven lithic scatters found in the intertidal zone of southern Haida Gwaii have been interpreted as remnants from the period of sharply rising sea levels that occurred in the region as the isostatic forebulge of displaced subcrustal material collapsed (Fedje et al. 2005c; Fedje et al. 2001; Mackie and Sumpter 2005). The archaeological sites date to around 9,400 BP when ocean waters transgressed through the current intertidal zone. Archaeological investigations have been carried out at one of these sites known as Kilgii Gwaay (Fedje et al. 2001; Fedje et al. 2005c). Unique at this site are well preserved wooden artifacts and faunal remains. Dates from archaeological materials indicate that the site was occupied between 9,460 and 9,260 BP.

Figure 14. Locations of early Holocene archaeological sites mentioned in text.

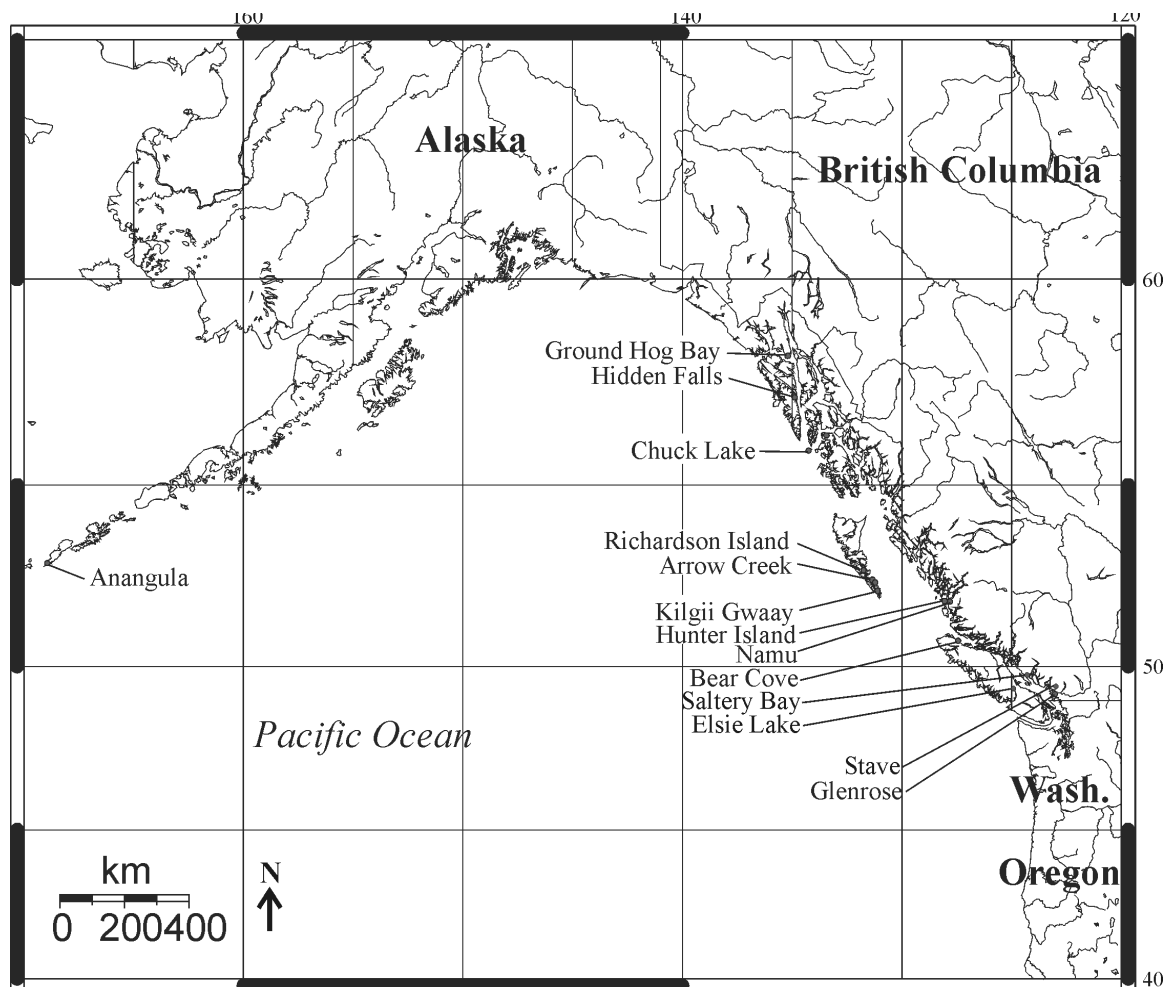


Table 6. Examples of early Holocene archaeological sites and elevations on the Northwest Coast of North America.

SITE AND LOCATION	CITATION	EARLIEST HOLOCENE DATE	SETTING (RELATIVE TO MODERN SHORE)	TECHNOLOGY
Anangula – Eastern Aleutian Islands	McCartney and Veltre (1996)	8,750 BP	Low plateau (between 12 and 18 m asl, <0.5 km inland)	Macroblade and core
Ground Hog Bay, Site 2	Ackerman (1996a; 1996b)	10,180 BP	On a glacio-marine terrace (17-18 m asl, <0.1 km inland)	Microblade tradition and foliate biface
Hidden Falls – southeast Alaska	Davis (1996); Ackerman (1996b)	9,500 BP	Lies in a low saddle on a point (8 m asl, <0.1 km inland)	Microblade tradition, foliate biface
On-Your-Knees – southeast Alaska	Dixon et al. (1997); Dixon (1999)	9,200 BP (microblade – human remains)	Cave (135 m asl, 0.5 km inland)	Microblade tradition, biface, human remains, maritime adaptation, bear hunting
Chuck Lake – southeast Alaska	Ackerman (1996b)	8,200 BP	On a ridge (15-18 m asl, <2 km inland)	Microblade tradition, bone tool, maritime adaptation
Richardson Island – Haida Gwaii	Fedje (2003)	9,290 BP	Terrace (15-16 m asl, ~0.1 km inland)	Kinggi complex, successive Microblade tradition (Early Moresby tradition), maritime adaptation
Arrow Creek Sites – Haida Gwaii	Fedje et al. (1996)	9,300 BP	Terraces (4, 7, and 17 m, up to 55 m inland)	Microblade tradition, maritime adaptation (fish trap?)
Kilgii Gwaay – Haida Gwaii + 110 intertidal sites	Fedje et al. (2001); Mackie and Sumpter (2005)	9,400 BP	1.5-2.5 m below high tide line (in intertidal zone)	Kinggi complex, bone tools, wood tools, maritime adaptation, bear hunting
Namu – Central Coast, BC	Carlson (1996a)	9,720 BP	Terrace (4 m asl, <50 m inland)	Pebble Tool tradition, successive Microblade tradition
Hunter Island – Central Coast, BC	Cannon (1999)	9,940 BP	Terrace (4-5 m asl, <50 m inland)	Basal shell midden deposits
Bear Cove – NE Vancouver Islands	Carlson (2003)	8,020 BP	Terrace (8-10 m asl, 30 m inland)	Pebble Tool tradition
Elsie Lake	Magne et al. (2006)	6,250 BP	Lake (20 km inland)	Microblade
Saltery Bay	Magne et al. (2006)	6,400 BP	Near present shoreline	Microblade
Stave Lake	McLaren et al. (2007)	9,230 BP	Stave Lake (72-80 m asl, 47 km inland)	PebbleTool tradition/stemmed point; successive microblade tradition
Milliken	Mitchell and Pokotylo (1996)	9,000 BP	Fraser River Canyon (70-90 m asl, 117 km inland)	Pebble Tool tradition

Following the initial occupation of Kilgii Gwaay, a significant stillstand is recorded as occurring between 9,000 and 5,000 BP between 13 and 15 m above the current high tide line (Fedje et al. 2005b). This stable and relict shoreline has been effectively prospected for archaeological remains from the early Holocene. In southern Haida Gwaii (Figure 14), most of the sites dating to this period are non-shell midden sites (Fedje and Christensen 1999). Faunal remains are uncommon with the exception of calcined bones recovered from the hearth features at the Richardson Island site (Steffen 2006). In the Naden Harbour region, on the northern end of Haida Gwaii, shell midden sites extend inland onto readily visible terraces and as a result of the elevations of these deposits, above the early Holocene stillstand, they may date to this time period (Stafford and Christensen 2000). A total of 14 archaeological sites are known from the highest relict marine terrace in Gwaii Haanas and 16 from northern Graham Island (Fedje et al. 2005a). To the north, early Holocene archaeological sites are known from raised marine terraces in Tlingit territory, including Ground Hog Bay II, Hidden Falls, and Chuck Lake (Ackerman 1996a, 1996b; Davis 1996) and from On-Your-Knees Cave on Prince of Wales Island (Dixon 1999; Lee 2001). To the south, significant archaeological sites dating to the early Holocene have been investigated at Namu (Carlson 1996a; Cannon 1999, 2003), Bear Cove (Carlson 2003), and Glenrose Cannery (Matson 1996), amongst others.

Technology

At Kilgii Gwaay, archaeological remains include a unifacial lithic industry and a ground bone industry (Fedje et al. 2005c; Fedje et al. 2001). With the exception of one fragment, no bifacial implements were found, possibly as a result of the seasonal use of

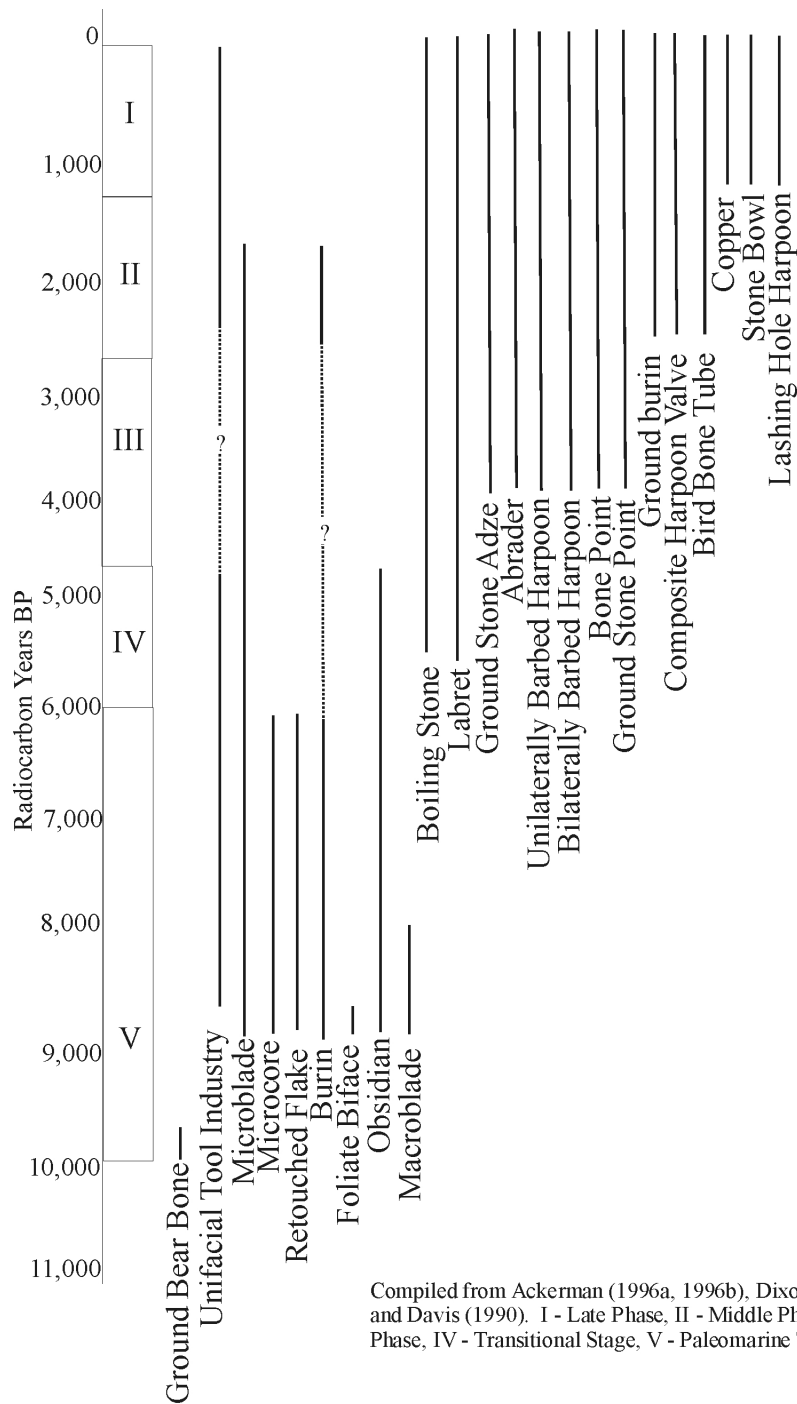
the site (McLaren et al. 2005). Other archaeological sites located in the intertidal zone in the southern Haida Gwaii, dating between 10,000 and 9,000 BP reveal the diversity of lithics used during this period, including foliate 'Xil' bifaces (Fedje et al. 1996; Fedje et al 2007b), microblade cores (Magne 1996), and other chipped stone tools and detritus (Fedje et al. 1996). Archaeological deposits from On-Your-Knees Cave on Prince of Wales Island include microblades, and foliate projectile points which date as old as 9,200 BP (Dixon 1999; Lee 2001).

Soon after the occupation at Kilgii Gwaay, there is a notable change in the archaeological record of the Northwest Coast. Archaeological evidence reveals that the earliest coastal inhabitants (pre-9,000 BP) did not use microblade technology. Rather, as indicated by the detailed stratigraphic record at the Richardson Island site, this technology was introduced shortly after 9,000 BP in Haida Gwaii (Magne 2004; Smith 2004) and at Namu on the Central Coast of British Columbia (Carlson 1996a). Coinciding with the adoption of microblade technology at the Richardson Island site is a change in projectile point types from Kuuxil to Kuuxilju (Fedje et al. 2008). There are also changes in the types of lithic raw material beginning at the same time (Smith 2004). These technological changes coincide with the cessation of sea level rise.

The presence of microblade technology as found earlier in southeast Alaska at Ground Hog Bay and Hidden Falls around 9,000 BP (Figure 15) is problematic due to dating and stratigraphic uncertainties at these sites (Ackerman 1996b; Davis 1996). If the chronology of microblade technology appearance from Richardson Island (Smith 2004) reflects regional patterns on Haida Gwaii, microblade cores found in the intertidal zone in the Haida Gwaii have likely been redeposited from raised beach sites rather than being

associated with the 9,400 BP transgression as has been previously suggested (Fedje et al. 1996).

Figure 15. Chart illustrating the types of artifacts found in the Tlingit region through time.



Compiled from Ackerman (1996a, 1996b), Dixon et al. (1997), and Davis (1990). I - Late Phase, II - Middle Phase, III - Early Phase, IV - Transitional Stage, V - Paleomarine Tradition.

The coastal Microblade Tradition (Carlson 1996c) is related technologically to the earlier and contemporary Alaskan Denali Complex and Siberian Diuktai Complex (Ackerman 1996b). The Pebble Tool tradition is similar in some respects to the interior Alaskan Nenana complex (Carlson 1998). It remains uncertain as to whether the Pebble Tool tradition relates to ancestral non-microblade complexes in Siberia (Goebel 2004; Holmes 2001). This is particularly the case since the non-microblade deposits at Ushki on the Kamchatka Peninsula have been re-excavated and re-dated later than the Denali and Nenana complexes in interior Alaska (Goebel et al. 2003).

In the interior of Alaska, the earliest archaeological sites have either non-microblade (Nenana complex) or microblade (Denali complex) bearing deposits that are earlier than those found on the Northwest Coast, dating to 12,360 BP (Largent 2004). The co-occurrence of microblade and non-microblade complexes in interior Alaska suggests that these separate complexes may reflect differences in site function rather than cultural differences. With the exception of Swan Point (12,360 BP) in the interior of Alaska (Holmes 2001; Largent 2004), all early interior Alaskan sites (dating from 11,800 BP) (Bever 2001), as well as Ushki in Siberia (11,200 BP) (Goebel et al. 2003), Richardson Island in Haida Gwaii (9,300 BP) (Fedje 2003; Magne 2004), and Namu on the British Columbia Central Coast (9,700 BP) (Carlson 1996a), lack microblade technology in their earliest deposits. The later appearance of microblade technology at these sites may represent a secondary migration from Siberian or Alaskan populations who used Diuktai Complex technologies (Magne and Fedje 2002; Powers and Hoffecker 1989).

In North America, the presence of microblade-bearing assemblages in the early period is unique to Alaska, the Yukon, and northern British Columbia in North America (Magne and Fedje 2002). The earliest dating sites on the southern Northwest Coast were originally found to lack microblade technology altogether, including Bear Cove on Vancouver Island (Carlson 2003), Glenrose Cannery on the Fraser River (Matson 1996), and Indian Sands in Oregon (Davis et al. 2004). However, more recent finds at Stave Lake, Saltery Bay, and Elsie Lake have uncovered evidence of an early Holocene microblade tradition on the south coast dating to at least 7,700 BP (McLaren 2006; Magne et al. 2006).

Microblades appear to have been used to arm slotted bone or antler projectile points (Ackerman 1996a; Christensen and Stafford 2005). On Haida Gwaii, a transition occurs sometime around 8,000 BP where this slotted point technology supplants biface projectile points (Fedje et al. 2008; Fladmark 1986). The apparent early Holocene disappearance of chipped stone bifaces is unique to Haida Gwaii (and possibly Southeast Alaska) on the Northwest Coast and is characterized in the local cultural historical sequence as the change from the early Moresby to late Moresby tradition (Fedje and Mackie 2005).

Subsistence

Overall, evidence from archaeological sites with preserved faunal assemblages reveals that early Holocene inhabitants of the northern Northwest Coast practiced a maritime-oriented subsistence economy. From the 9,460 to 9,260 BP deposits at Kilgii Gwaay, subsistence is primarily maritime-oriented, focussing on intertidal shellfish, waterfowl, sea mammals, and abundant fish (Fedje et al. 2001). The bear remains from

this site suggest that land mammals were used to supplement the marine diet (McLaren et al. 2005). Similarly, faunal remains from Richardson Island (Steffen 2006), Chuck Lake (Ackerman 1996b), Coho Creek (Christensen and Stafford 2005), and Namu (Cannon 1996) all reveal a heavy reliance upon maritime subsistence.

Some researchers have questioned whether early human populations on the Northwest Coast were maritime adapted (Coupland 1998; Matson and Coupland 1995). These researchers suggest that the initial peopling of the Northwest Coast occurred as a result of the expansion of big game hunters from inland areas. Evidence cited for this early pre-maritime population is based primarily on faunal remains. This interpretation has been questioned as a result of re-analyses of early Holocene faunal components and improved collection techniques (Carlson 2003; Coupland and Stewart 2005; Steffen 2006). Indeed, when all of the evidence from Pleistocene-Holocene transition archaeological sites from the Pacific Coast of the Americas is considered, there is indication that inhabitants lived on islands only accessible by boat and used a wide variety of nearshore and offshore marine resources (Fedje et al. 2001; Fedje et al. 2005c; Steffen 2006).

Settlement Patterns

Mackie and Sumpter (2005) found considerable difference between early Holocene and late Holocene site settlement patterns in southern Haida Gwaii. Early Holocene settlement patterns were assessed using data from the 111 intertidal sites that date between 10,000 and 9,000 BP which were occupied during the period of rapidly rising sea levels. The results of their analysis reveal that early sites are more likely to be located “behind elaborate shorelines, protected gravel beaches, on east-facing shores,

near accessible marine resources as indicated by seabird nesting areas, and close to or near salmon streams” (Mackie and Sumpter 2005: 369). They assert that the speed of sea level rise, on average 3 m every 60 years:

would have had a profound effect on the strategies for survival; a high degree of flexibility in settlement placement and a low degree of sedentism would have been essential. Houses are likely to have been small and mobile. Repeated use of sites would have been possible for only a few decades. Large populations and long-term accumulation of wealth and possessions would be more difficult to sustain. Food is more likely to have been stored in purpose-built caches or procured as needed. There could have been a tendency to place more complex sites behind steep foreshores or on small heights of land where they would not be overrun by rising sea levels. Ownership or other control of access to resources is likely to have been generalized across a territory, and territory boundaries would, by definition, be fluid. Consequently, a highly stratified society would have been unlikely [Mackie and Sumpter 2005: 368].

Lithic raw material assessments from southern Haida Gwaii suggest that early Holocene inhabitants at the Richardson Island site (9,400-8,500 BP) used only locally available raw materials (Smith 2004). Obsidian sourced to Mount Edziza has been found in early Holocene contexts at Ground Hog Bay II (Ackerman 1996) and On-Your-Knees cave (Lee 2001). Similarly, obsidian from the Rainbow Mountains is the dominant type of obsidian in the early Holocene archaeological deposits at Namu (Carlson 1994, 1996b) revealing that trade and travel on the mainland may have been more extensive than on Haida Gwaii.

Human Remains

Human remains have been found at two different early Holocene contexts on the Northwest Coast: On-Your-Knees Cave and at Namu. The 9,200 BP (after marine reservoir correction) human remains from On-Your-Knees Cave in Southeast Alaska have a carbon isotope signature suggesting a highly marine-oriented diet (Dixon et. al. 1997) reinforcing the evidence for marine adaptation. The remains from Namu include only the crowns of teeth dating between 9,000 and 6,500 BP. These are characteristically of “the Sinodont type of dentition common to northeast Asia and the New World” (Carlson 1996c: 3) thus emphasizing the connection between the people of these two regions of the globe.

The Late Holocene Archaeological Record

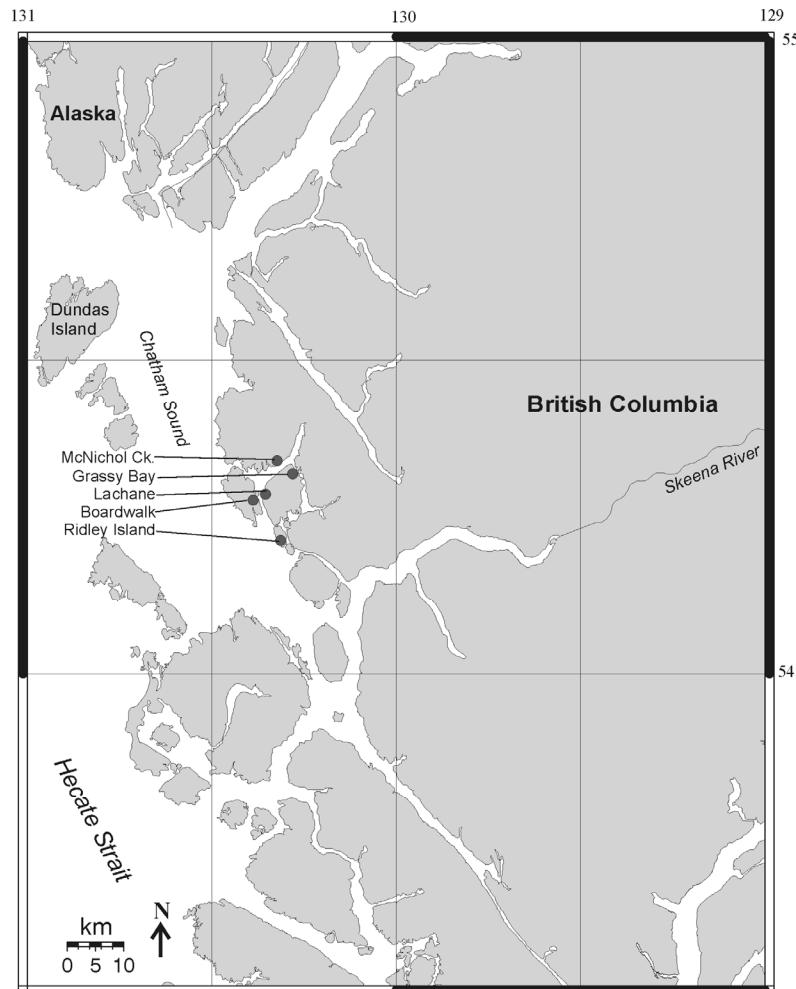
With an increase in the number of known and excavated sites postdating the beginning of the Holocene, archaeological research of later periods on the Northwest Coast has been focussed on the development of the ethnographic cultural patterns, adaptations to changes in the environment, cultural-historical relationships, and the development of cultural complexity (Fedje and Mackie 2005). The archaeology of the early Holocene is often compared to the archaeology of later time periods as a means of arguing for long-term continuity of cultural practices (Cannon 2003; R. Carlson 1998; C. Carlson 2003), or for arguing disjuncture of cultural practices from terrestrially oriented to marine (Coupland 1998; Matson and Coupland 1995), from egalitarian to stratified social organization (Carlson 1996b), from mobile to sedentary (Mackie and Sumpter 2005), and from chipped stone technologies to ground and pecked stone technologies (Carlson 1996b).

The late Holocene is a time period which is much more familiar to coastal archaeologists than earlier time periods. In many respects this is primarily the result of archaeological visibility: very large later Holocene archaeological sites tend to be extremely visible shell middens located along present day shorelines and watercourses.

Unlike earlier time periods, the archaeology of the northern Northwest Coast is best documented in Tsimshian territory (Figure 16), in particular the Prince Rupert Harbour region (Ames 2005; Archer 2001; Fladmark et al. 1990; MacDonald 1969; MacDonald and Cybulski 2001; MacDonald and Inglis 1981). The late Holocene archaeological record in southeast Alaska is generally considered in relation to the Prince Rupert Harbour sequence. On Haida Gwaii it is referred to as the Graham Tradition (Mackie and Acheson 2005). Regardless of the intensity of archaeological research in the Prince Rupert Harbour region, there has been a complete lack of known archaeological sites that pre-date 5,000 BP. For this reason the Prince Rupert Harbour cultural historical sequence begins at 5,000 BP (Ames 2005; Coupland 1996). A distinct archaeological sequence is described for the Skeena River near Terrace, which begins at 5,050 BP (Coupland 1996). This sequence shows alternating influences from interior and coastal areas (Allaire 1979; Ames 1979; Fladmark et al. 1990).

Archaeological research in Prince Rupert Harbour has focussed on preliminary site discovery and testing (Ames 2005; Archer 2001; Drucker 1943; Smith 1909), the construction of a cultural-historical sequence for the region (Fladmark et al. 1990; MacDonald 1969; MacDonald and Inglis 1981), the search for evidence of Tlingit expansion into the area as related by oral history (Archer 2001; MacDonald and Cybulski 2001; MacDonald 1969; Marsden 2000; Martindale and Marsden 2003), and explaining

Figure 16. Locations of late Holocene archaeological sites mentioned in text.



the timing and reasons for the origins of social class distinctions (Ames 2005; Coupland et al. 2003; MacDonald and Inglis 1981). Ames (2005) lists 127 radiocarbon dates from 11 archaeological sites as forming the chronological basis for the Prince Rupert Harbour archaeological record. The regional sequence has been separated into three distinct units that are described in MacDonald and Inglis (1981); Fladmark et al. (1990); and Ames (2005): Prince Rupert Harbour III (5,000-3,500 BP), Prince Rupert Harbour II (3,500-1,500 BP), and Prince Rupert Harbour I (1,500-200 BP). Overall artifact types are

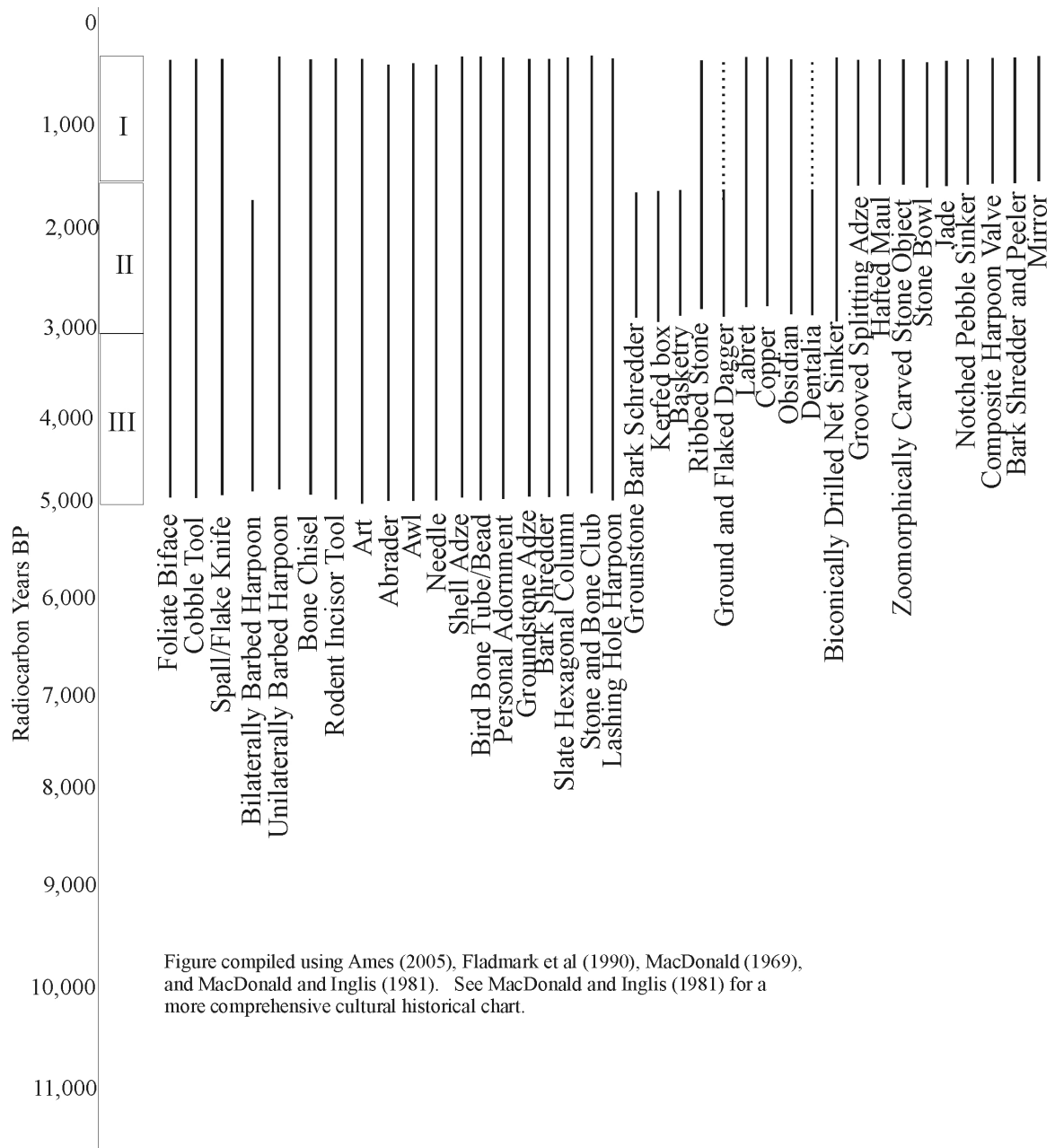
similar throughout all of these periods, with most significant differences being the result of sampling (Ames 2005).

Technology

By comparing the early archaeological record of the northern Northwest Coast with the late Holocene record of Prince Rupert Harbour, there is a notable and profound change in the types of cultural materials that occur just prior to 5,000 years BP: the adoption of ground stone technology. At this same time a diminution of chipped stone tool manufacturing occurs. The manufacture of chipped stone bifaces seems to disappear on Haida Gwaii in the early Holocene, however, these types of tool are present in the late Holocene Prince Rupert Harbour sequence. Microblade technology seems to disappear from most coastal sites shortly after 5,000 BP. Moss et al. (2007) suggest that the timing of clear cultural change on the Northwest Coast is better placed as occurring after 4,300 BP and emphasizes that components with chipped stone, including a few microblade bearing components, continue into the late Holocene.

In the archaeological record from Prince Rupert Harbour III, bone and antler tools are found with greatest frequency (Figure 17). Lithics include a cobble and spall industry, some bifaces and ground stone. Microblade technology is absent. Cultural material from the Prince Rupert Harbour II period is similar in many respects to the previous period but is complemented by wood and fibre artifacts excavated at waterlogged sites (MacDonald and Inglis 1981). During Prince Rupert Harbour I, material culture is similar to the previous periods although grooved splitting adzes and hafted mauls are added to the wood working industry, some with zoomorphic design, and

Figure 17. Chart illustrating the types of artifacts found in the Prince Rupert Harbour area.



overall decorated artifacts are more common. In general, there is a pronounced pattern of continuity in the components from the late Holocene in the Prince Rupert Harbour region (Figure 17). The increased dominance of western red cedar on the landscape after 5,000

BP likely had a profound effect on the technologies employed (Hebda and Mathewes 1984).

Subsistence

A major difference between the early and late Holocene on the northern Northwest coast is the appearance (and preservation) of large shell midden habitation sites (Ames 2005; Archer 2001; Fladmark 1975; Mackie and Acheson 2005; Moss 2004a; Moss et al. 2007). Additionally, some researchers have suggested that salmon populations became stabilized after 5,000 BP when the gradients of major rivers had stabilized following isostatic rebound, crustal tilt, and channel downcutting (Fladmark 1975).

It has been suggested that earlier Coast Tsimshian populations placed a heavier reliance on land mammals (Fladmark et al. 1990). Overall, sites excavated in the late 1960s have large percentages of mammal remains in their assemblages: 91% at the Boardwalk site and 76% at the Grassy Bay site. Recent excavations undertaken at the Boardwalk site have shown that the high proportion of land mammals can be attributed to the lack of screening employed during the earlier excavations at the site; rather than a mammal based economy as in these later excavations salmon were found to make up over 90% of the faunal assemblage (Coupland and Stewart 2005). This is also supported by faunal remains from McNichol Creek and Ridley Island (GbTn-19) which have assemblages with over 90% salmon elements (Stewart and Stewart 2001).

Settlement Patterns and Human Remains

While large shell midden and village sites reveal increased sedentism and social stratification during the late Holocene, there appears to have been a contemporaneous rise

in warfare. In the Prince Rupert Harbour area most of these interpretations come from examinations of over 100 burials, some of which show evidence of differentiated social status and injury interpreted as being the result of warfare (MacDonald and Cybulski 2001). Curiously there is little in the cultural historical sequence of material goods that would suggest an abrupt population replacement as is related by the oral historical traditions from the area (MacDonald 1969). Tsimshian and Tlingit groups may have used very similar tool kits and eaten similar foods, and for this reason the population shifts may not be evident from material culture alone. There are, however, other lines of evidence that have been drawn upon to interpret tensions between Tsimshian and neighbouring populations. In particular, burials from Prince Rupert Harbour II have a tendency to show parry fractures and depressed skull fractures, likely resulting from conflict-related club wounds (MacDonald and Cybulski 2001). Additional evidence suggests that many of the midden sites in Prince Rupert Harbour were abandoned between 2,000 and 1,600 BP (Archer 2001). Other evidence is found in specific events related in the oral history of this time period that have archaeological analogues revealed through excavations (Marsden 2000). For example, decapitations of captured Tlingit undertaken by Aksk at his fort, known to archaeologists as the Lachane site, where the remains of three of the burials show evidence of decapitation (MacDonald and Cybulski 2001). These remains date to 1750 BP.

Conclusions

In an effort to provide a context for conducting a focussed archaeological survey project aimed at finding early archaeological sites on the Dundas Island, this chapter has summarized the archaeology of the northern Northwest Coast. Research focusing on

archaeological sites dating to the Pleistocene-Holocene transition raises several issues. Despite the modeling of the Northwest Coast of North America as a possible route by which the Americas were first occupied, no convincing archaeological evidence of this has been found. The early coastal technological traditions seem to have more in common with interior Alaskan and Siberian traditions than other North American archaeological complexes such as Clovis, Folsom, or Plano. This is perhaps not surprising as the antiquity of maritime adaptation is suggested by the archaeological record and is now accepted by most researchers. It seems increasingly likely that the first inhabitants of the Northwest Coast were derived from Siberian coastal migrants who were maritime adapted and who used watercraft regardless of whether these were the first people in the Americas or not.

All late Pleistocene and early Holocene archaeological sites on the northern Northwest Coast are located on relict shoreline features or are associated with areas of inland of the shoreline. Based on the archaeological record from this region the following archaeological materials were expected in the early sites of the study area: microblades, foliate-shaped bifacial implements, and abundant chipped stone. Archaeological materials that would be unexpected include: ground stone implements, a reliance on salmon, large shell middens, a well developed cedar harvesting and manufacturing industry. With these expectations in mind, the search for early period archaeological sites on the Dundas Islands was undertaken.

*Chapter V – Dundas Island Archipelago Vegetation History as
Reconstructed through Pollen Analysis*

Introduction

Late Pleistocene and early Holocene environments, as reconstructed from pollen analysis of the north coast of British Columbia, are best known from Haida Gwaii (Fedje 1993; Hebda et al. 2005; Heusser 1955; Lacourse and Mathewes 2005; Mathewes and Clague 1982; Warner et al. 1982) as discussed in “Chapter III – Palaeo-Environmental Context”. From the shore of the eastern Hecate Strait region much less information on the late Pleistocene period exists, limited to studies near the Prince Rupert Harbour (Banner et al. 1983; Turunen and Turunen 2003). Although general patterns in vegetation change appear to have occurred coast-wide (Hebda and Whitlock 1997), changes in vegetation communities were regionally specific, in particular on small islands (e.g., Hebda et al. 2005).

Vegetation sequences dating from the late-glacial are known from Haida Gwaii and locations in southeast Alaska and northern Vancouver Island (Fedje 1993; Hansen and Engstrom 1996, Hebda 1983, 1997; Heusser 1955; Lacourse and Mathewes 2005; Mathewes and Clague 1982). It is likely that there are many similarities between the study area and those in other north coastal regions. However, the suspected isolation of the Dundas Islands from the mainland since the time of the last glacial maximum may have resulted in local variation in vegetation communities.

Two studies of vegetation communities have been undertaken in the Prince Rupert region. Both studies focussed on the history of paludification: the development of a bog

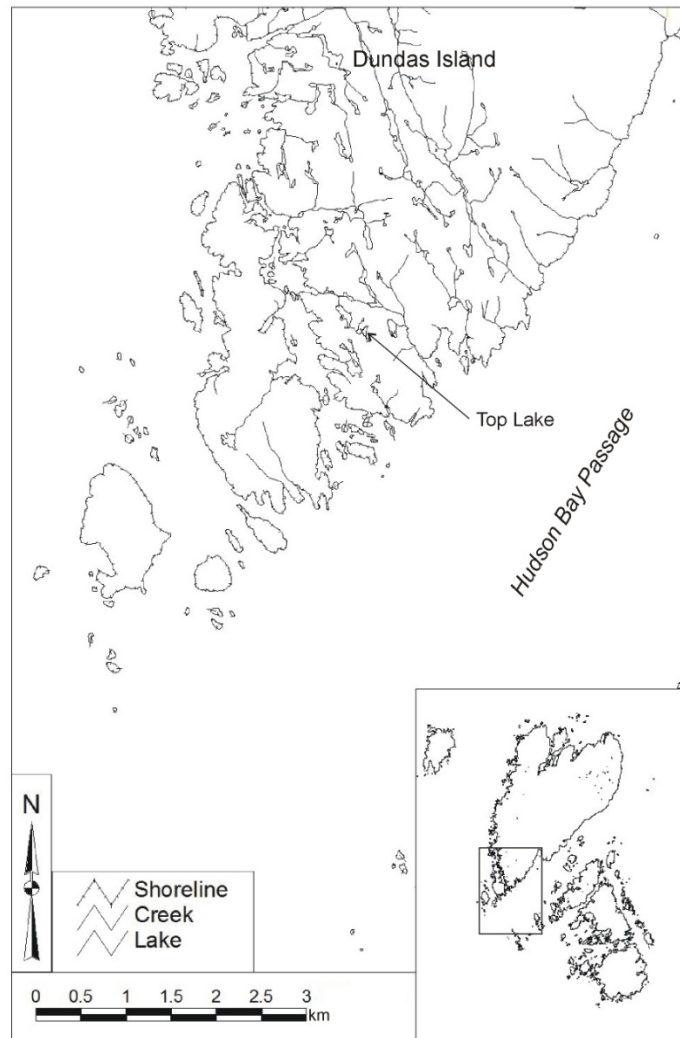
woodland (Banner et al. 1983) and a slope bog (Turunen and Turunen 2003). Banner et al. (1983) present a pollen diagram that begins at 8,700 BP. Turunen and Turunen (2003) analyzed multiple core samples and despite having a record that extends to 10,180 BP, they only present a sequence that begins at 7,460 BP. These pollen sequences from the east side of Hecate Strait do not include late Pleistocene and earliest Holocene pollen assemblages in their sequences.

Analysis of pollen taken from a lake core on Dundas Island was undertaken to describe conditions in the study area and to gain an understanding of local terrestrial palaeo-environments as indicated through reconstructed vegetation communities.

Study Site

Top Lake is situated on southwestern Dundas Island (Figure 18). The sill of this lake is 33 m above barnacle line (abl) as measured by altimeter. The lakebed was found to be 1.25 m below where the core was taken. A core of 634 cm of sediment was recovered from the bottom of this lake. Based on a diatom analysis from the cores taken from other lakes of lower elevation, sea levels have been lower than 15 m above the barnacle line (abl) since 12,385 BP (See “Chapter VI - Dundas Island Archipelago Late Pleistocene and Holocene Sea Level History”). Consequently, the pollen sequence from Top Lake represents terrestrial conditions since the late Pleistocene and early Holocene period. Top Lake is surrounded by blanket bog, rocky outcrops, and some steep areas with scrub forests.

Figure 18. Location of Top Lake on Dundas Island.



The following plant species currently occur in the vicinity of the lake: *C. nootkatensis* (yellow cedar), *P. contorta*, *T. heterophylla*, *Taxus brevifolia* (western yew), *Gaultheria shallon* (salal), *Ledum sp.* (Labrador tea), *Veratrum viride* (false hellebore), *Lysichiton americanum* (skunk cabbage), *Nuphar polysepalum* (yellow pond lily), *Pteridium aquilinum* (bracken fern), *Empetrum nigrum* (crowberry), *Blechnum spicant* (deer fern), *Eriophorum chamissonis* (Chamisso's cotton-grass), *Kalmia microphylla occidentalis* (western bog-laurel), *Myrica gale* (sweet gale), *Pinguicula villosa* (hairy

butterwort), *Vaccinium uliginosum* (bog blueberry), *Viola langsdorfii* (Alaska violet), and several *Sphagnum* species (peat moss).

Methods

Top Lake was cored using a Livingstone piston-coring device on a platform lashed on two canoes. The canoes were stabilized by anchoring them at three different places on the shore of the lake. A portion of the core, between 585 and 579 cm depth below surface (dbs) was lost during field extraction. Sediment samples were recovered in 1 m sections wrapped in cellophane and placed in core tubes. Notes were made in the field as to the location and procedures undertaken. Cores were transported from Dundas Island to the Pacific Geoscience Centre in North Saanich where they were stored in refrigerated conditions until being transferred to a refrigerator in the archaeology lab at the University of Victoria. The stratigraphy of the core was examined in the field and logged in the lab.

Sample Preparation

Samples measuring 1 cm³ were collected from the Top Lake core. The lowest and earliest parts of the core were sampled at 5 cm intervals. Intervals of 2 cm were used at sedimentary transitions, such the change from clay to gyttja. For the remaining sediments, samples were taken at 25 cm intervals to establish a vegetation history framework and facilitate regional correlations.

Laboratory methods for pollen processing and identification followed those outlined by Faegri and Iversen (1975). Samples with high percentages of mineral sediment were initially prepared by treatment with hydrochloric acid (HCl) followed by hydrofluoric acid (HF). These treatments were undertaken to dissolve bedrock derived

carbonates and silicates. In all of the samples prepared *Lycopodium* spores were added with 10,679 spores per tablet. This was done to calculate pollen density and pollen accumulation rates. Following this, all samples were dehydrated in glacial acetic acid and processed by boiling with acetolysis. They were then rehydrated, rinsed, and mounted on slides using glycerine jelly. Samples with high amounts of remaining fine particles were screened through a 10 µm Nitex screen and concentrated by centrifuging the samples in small, glass centrifuge vials before mounting on glass slides. In the lowest parts of the core, below 620 cm db, pollen grains were uncommon based on observations made on preliminary slides, and were thus re-sampled and processed using 3 cm³ of sediment.

Plant macrofossils were selected and sent for radiocarbon analysis. Samples were processed at Lawrence Livermore National Laboratory's Center for Accelerator Mass Spectrometry in California (CAMS), W.M. Keck Carbon Cycle Accelerator Mass Spectrometry Laboratory, also in California (UCIAMS), and Beta Analytic Inc. in Florida (BETA).

Pollen Identification and Quantification

Pollen and spores were identified using the comparative collection housed at the Royal British Columbia Museum in Victoria. Additional resources were used to help in identification, including the pollen identification key in Moore and Webb (1978), a selection of excellent photographs of grains and spores from the Northwest Coast produced by David Mazzuchi (University of Victoria), and the expert knowledge and experience of Dr. Richard Hebda (University of Victoria/Royal British Columbia

Museum). Where possible, a maximum of 300 pollen grains and spores per sample were counted per sample analyzed. Deeper samples were found to have very low concentrations of pollen and spores and in some instances only 100 palynomorphs were counted.

The methods of the pollen analysis were learned as a part of this dissertation project. I had support and guidance in the identification process. Dr. Richard Hebda was very helpful in clarifying my identifications of unfamiliar pollen. The first slides that I counted were returned to at a later date and questionable identifications were verified.

A pollen diagram was created using PSIMPOLL (Bennet 2002), a computer program specifically designed for plotting pollen diagrams and analyzing pollen data. Distinct pollen zones were identified through agglomeration using constrained cluster analysis based on squared Euclidian dissimilarity (CONISS) (Bennett 2002).

Results

Stratigraphy and Radiocarbon Dates

The core has three distinct sediment types (Figure 19). The lowest stratum (634-570 cm) consists of compact grey clay with occasional small pebble-sized clasts. The grey clay may be aeolian in origin and the pebbles eroded from the area surrounding the lake. These characteristics suggest that the local landscape was relatively barren of vegetation and that erosion and wind-transported sediments were common locally. Fizzing noted during HCl treatment suggests that at least a component of this sediment is derived from carbonate bedrock. The middle stratum (570-560 cm) consists of brownish green clay and has a greater amount of organic matter than the sediment below. The upper stratum (560-0 cm) is a dark brownish-black gyttja with a greasy feel and little

apparent mineral component when viewed microscopically. Organic accumulation dominates this unit, suggesting a continuous blanket of vegetation had covered much of the local area.

Eight radiocarbon dating plant macrofossil samples were selected and submitted (Table 7). The first three dates that were submitted for analysis were sampled from near the top of the lowermost core section. From a regional perspective, these dates, 11,490 BP, 9,570 BP, and 9,520 BP, are inconsistent with the grey clay sediments from which they were sampled. Generally, grey clay deposits were replaced by higher densities of organic deposits with the onset of the pine zone between 13,000 and 12,000 BP (Hansen and Engstrom 1996; Heusser 1955; Mathewes and Clague 1982). From all other lakes cored and dates on the Dundas Islands, this transition occurs before 12,000 BP unless there is marine influence. As is seen in “Chapter VI - Dundas Island Archipelago Late Pleistocene and Holocene Sea Level ” sea-level was far below 33 m between 11,000 and 9,500 BP.

Table 7. Summary of transitions and dates from lake cores sampled in 2001.

LOCATION, LAB#	SAMPLE	DEPTH (CM DBS)	MACRO-FOSSIL	¹⁴ C AGE	+/- 1 SD
BETA 235596	Top Lake	136	W. hemlock needle and cone bract	5,090	40
BETA 235597	Top Lake	337	W. hemlock needle and charred material	9,810	40
UCIAMS 31733	Top Lake	543	Pine needle	10,565	50
UCIAMS 30933	Top Lake	555	Pine needle	12,250	50
UCIAMS 31734	Top Lake	561	Seed	12,385	30
CAMS 82219*	Top Lake	595	Leaf fragment	9,570	80
CAMS 87244*	Top Lake	595	Leaf fragment.	9,520	60
CAMS 82218*	Top Lake	599	Unidentified plant material	11,490	45

*Rejected Date

The use of a Livingston piston corer may contribute to younger dates being associated with older sediments. The reason for this is that the corer only samples 1 m of

deposit at a time. To get deeper samples the coring device must be reinserted into the core hole where it invariably picks up material from the sidewalls. This can be difficult to control and the topmost deposits of any 1 m section of core may be contaminated in this manner. Deeper sediments in each core section will be less likely to be contaminated. To test the possibility that the first three date samples submitted were contaminated in this manner, three additional date samples were run from the bottom of the next core section up in the sample (584-487 cm dbs) and thus in a more securely sampled context. The following dates were recovered 12,385 \pm 30 BP (UCIAMS 31734) from 561 cm dbs, 12,250 \pm 50 BP (UCIAMS 30933) from 555 cm dbs, and 10,565 \pm 50 BP (UCIAMS 31733) from 543 cm dbs. These radiocarbon samples and dates are more consistent with the types of sediments they are associated with, and suggest that lower dates, the first three submitted, are the remnants of contamination and they have been discarded. Two additional samples were submitted from later sediments in the core and resulted in dates of 9810 \pm 40 BP (BETA 235597) from 337 cm dbs, and 5090 \pm 40 BP (BETA 235596) from 136 cm dbs demonstrating stratigraphic consistency.

Pollen and Spore Zones

A total of six distinct vegetation zones are apparent from the data collected (Figure 19). In general, arboreal pollen increases in the assemblage relative to non-arboreal pollen after 12,385 BP (Figure 20). The concentration of pollen in the lowest levels of the core is very low compared to later deposits (Figure 21).

Zone TL I – Alder, Pine, Grass and Ferns (634-595 cm dbs) >12,385 BP

The assemblage is characterized by low values of *P. contorta* pollen (below 20%) and abundant *Alnus* and notable Poaceae values. Monoletic fern spores include those

with verrucate form (cf. *Polypodium*), and Monolete undifferentiated ferns. Other notable pollen types are Poaceae and Cyperaceae with minor amounts of *Populus*, *Salix*, Ericaceae, Rosaceae, and Liliaceae. Traces of some coniferous pollen other than *P. contorta* are also present: *Abies* (possibly subalpine fir), *T. heterophylla*, *Picea*, *T. mertensiana*. Shrubs appear to have been the dominant vegetation during this period assuming that the alder pollen is *Alnus crispa*. Overall the ecological conditions suggested by the assemblage were open landscapes dominated by non-arboreal species, but with a few scattered trees. The low frequency of *P. contorta* pollen may be the result of long distant transport (Hebda and Allen 1993).

Figure 19. Percentage pollen diagram from Top Lake on Dundas Island, zonation created using CONISS.

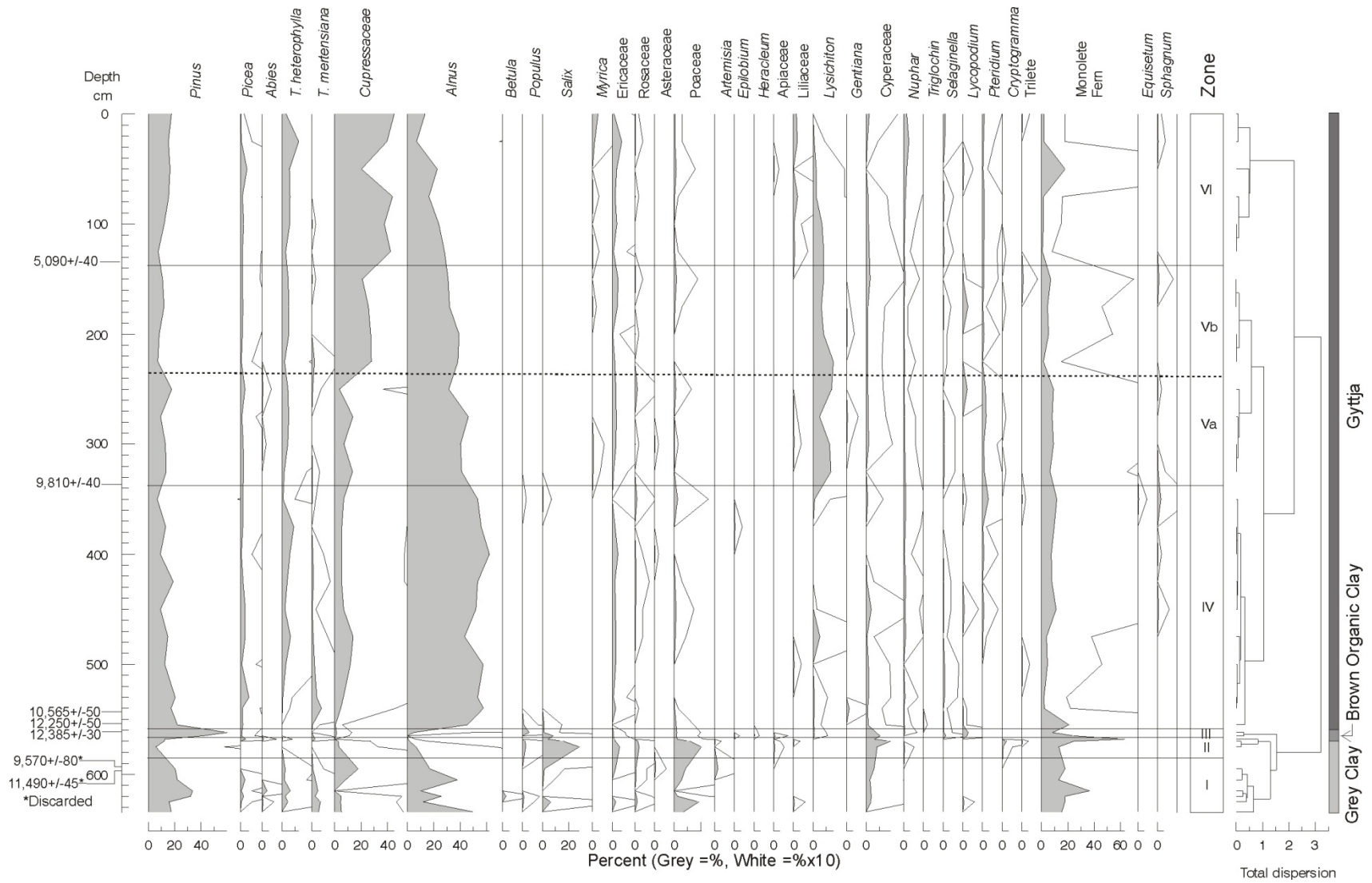


Figure 20. Comparison of percentage of arboreal and non-arboreal pollen. *Alnus* pollen may be arboreal or non-arboreal and is considered separately. Spores are not considered.

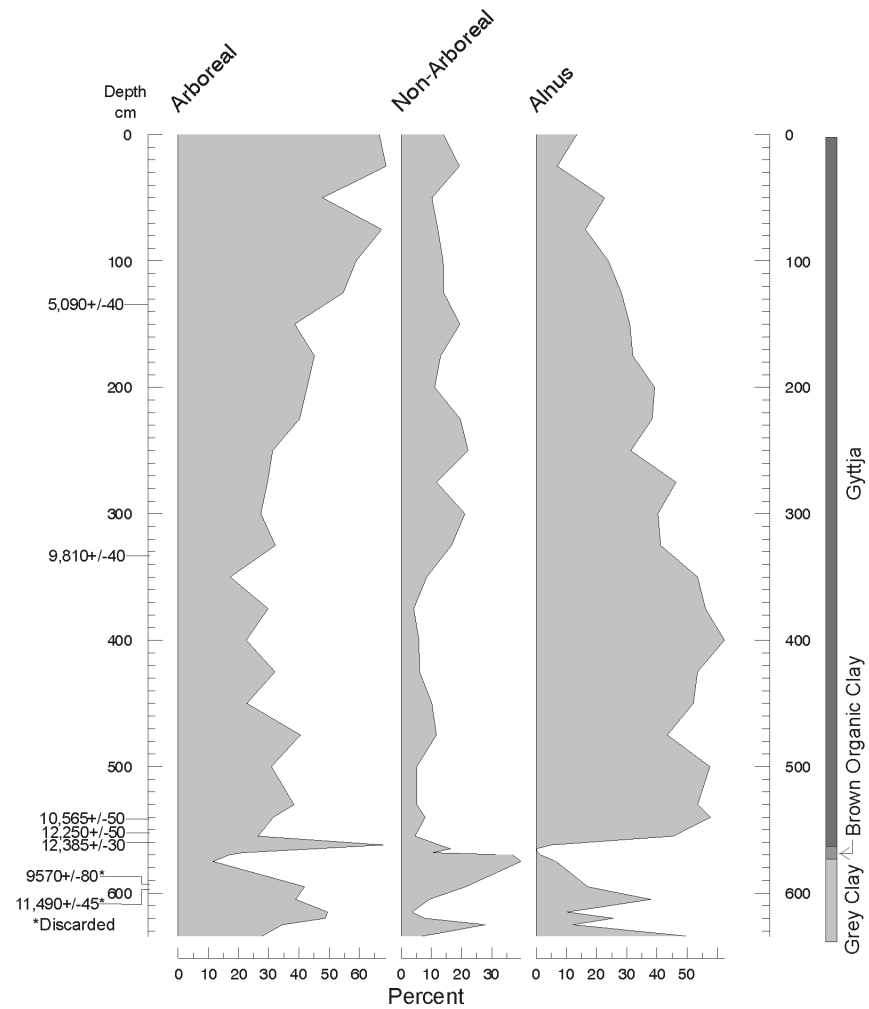
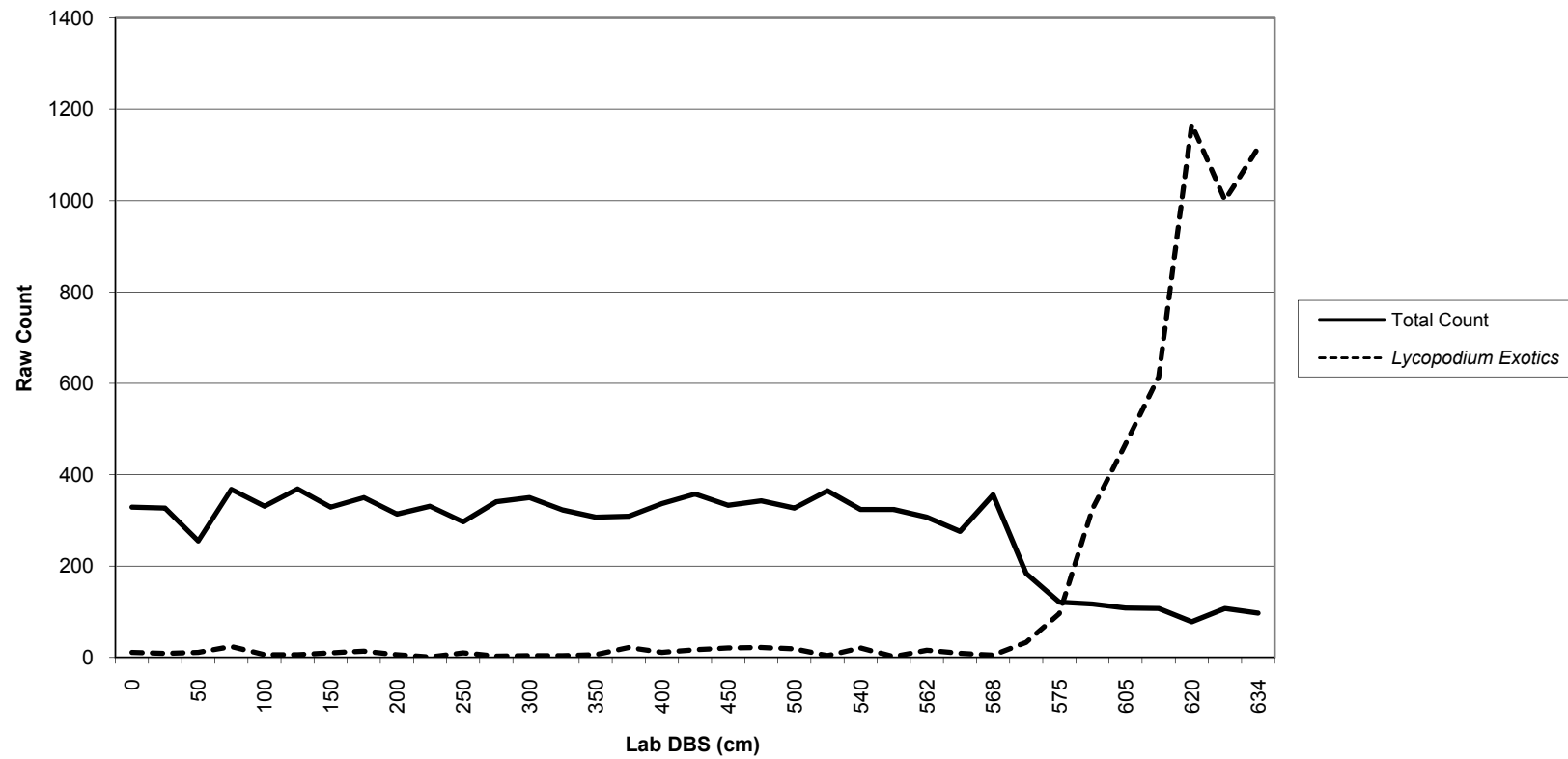


Figure 21. Comparison of pollen and spores counted to exotic *Lycopodium* added to each sample.



Zone TL II – Willow, Grass, and Sedge (575-568 cm dbs) >12,385 BP

A marked increase in non-arboreal pollen occurs between 575-568 cm that predates 12,385 \pm 30 BP (the transition between Zone I and Zone II, 585-579 cm dbs was lost during lake core extraction) (Figure 19). *P. contorta* pollen drops to between 5 and 12% of the assemblage. All other conifer pollen is lacking or at low levels. *Alnus* pollen decreases to below 1% of the assemblage. Dominating this zone are *Salix*, Poaceae, and Polypodiaceae. Also Ericaceae, Rosaceae, *Populus*, *Artemisia*, Apiaceae, and Cyperaceae are present and a notable occurrence of *Cryptogramma* fern.

This assemblage indicates there was a change from an open scattered tree landscape to a fully open landscape. Shrubs, grasses, and a diversity of herbs dominated the environment. The pollen suggests that the landscape was steppe-like. This *Salix* rich ecological setting is similar to the prostrate-shrub tundra found in the arctic coastal plain of Alaska (Oswald et al. 2003).

Zone TL III – Pine Parkland (565-562 cm dbs) 12,385 BP – 12,250 BP

A brief period of time is represented by this zone which is characterized by the resurgence of arboreal pollen. It is represented by only two samples in the core analyzed, between 565 and 557 cm dbs (Figure 19). A radiocarbon sample from 561 cm dbs was dated to 12,385 \pm 30 BP. *P. contorta* pollen increases up to 60% of the assemblage. *Populus* (poplar) is notable in this zone, but *Alnus* is almost absent. Low percentages of diverse non-arboreal pollen types include Ericaceae, Poaceae, *Epilobium*, *Heracleum*, and Apiaceae. *Lysichiton*, *Selaginella*, and *Lycopodium* also make an appearance in the assemblage. Polypodiaceae fern spores are abundant (20-60%).

Herbs are relatively abundant in the assemblage suggesting open conditions despite the dominance of pine. This assemblage reveals the occurrence of an open pine forest with a substantial herbaceous understory similar to that described during the same time period elsewhere on the northern Northwest Coast (Hebda et al 2005; Lacourse and Mathewes 2005). Conditions were likely drier and warmer than previously, allowing for the re-establishment of pine.

Zone TL IV – Alder and Mixed Conifers (555-350 cm dbs) 12,250 - 9810 BP.

This zone begins by a marked increase in *Alnus* pollen (40-50%) and modest values for several coniferous species (Figure 19). The abundance of *P. contorta* pollen in the assemblage diminishes from the previous zone as coniferous taxa increase including *Picea*, *T. heterophylla*, Cupressaceae, and *T. mertensiana*. The increase in arboreal pollen is complemented by a decrease and change in composition of the herbaceous assemblage. The pollen of wetland taxa present in this zone include *Lysichiton* pollen and *Nuphar*. Ericaceae is a notable type in this zone. There is a decrease in the amount of *Polypodium* fern type spores at the same time as *Pteridium* spores and undifferentiated monoletic fern species increase. *Sphagnum* spores make their first appearance in this zone.

The ecological conditions suggested by the pollen of this zone reveal that mixed coniferous forests had become established on the landscape, albeit different in comparison to contemporaneous *Picea* dominant forest development on Haida Gwaii (Hebda et al. 2005; Lacourse and Mathewes 2005). Localized wetlands characterized by *Lysichiton* and *Nuphar* were present but the appearance of *Sphagnum* suggests bog lands had begun to develop. The increase in *T. mertensiana* associated with the date of

10,565+/-50 is consistent with increases in this species noted during the Younger Dryas interval pollen assemblages on the northern Northwest Coast (Mathewes 1993).

Zone TL V – Alder, Cedar, Skunk Cabbage and Pine (325-150 cm dbs) 9810 to 5090 BP

This zone is distinguished by an increase in the amount of Cupressaceae and *Lysichiton* pollen (Figure 19). Overall, *Alnus* remains the dominant pollen type. Cupressaceae pollen (most likely red and yellow cedar) increases markedly at 225 cm dbs and this zone is subdivided into “TL Va” and “TL Vb” based on this change. Ericaceae and *Nuphar* remain important and ferns are dominated by monolete undifferentiated types and *Pteridium* spores. *Sphagnum* spores continue.

The increase in *Lysichiton* pollen suggests that the ecology of the area became increasingly dominated by wetlands. Although there was an increase in the amount of conifer taxa, alder remained the dominant species. The alder and coniferous signatures suggest that there were treed areas, likely on steep slopes which were unable to support blanket bogs, and in particular around the coastal fringe.

Zone TL VI – Cedar, Alder, and Pine (125-0 cm dbs) 5090 BP to present

Cupressaceae (red and yellow cedar) is the most abundant pollen type in this zone and *Alnus* (alder) declines slightly but is still important compared to zone “TL V” (Figure 19). A slight increase in the abundance of *T. heterophylla* and *P. contorta* pollen is notable. An increase in *Myrica*, Ericaceae, Liliaceae, and *Nuphar* pollen is also noteworthy. Undifferentiated monolete ferns remain the dominant fern spores.

This zone reflects the ecological conditions found in the area today, with cedar and pine forests on steep slopes (Figure 22), cedar and pine bog forests in gently sloped

areas, pine and sphagnum bog in flat areas, and alder along creeks and the marine shoreline. Western hemlock and Sitka spruce are limited to sites with better drainage where soils are less acidic, generally near the coastal fringe and along faster moving creeks.

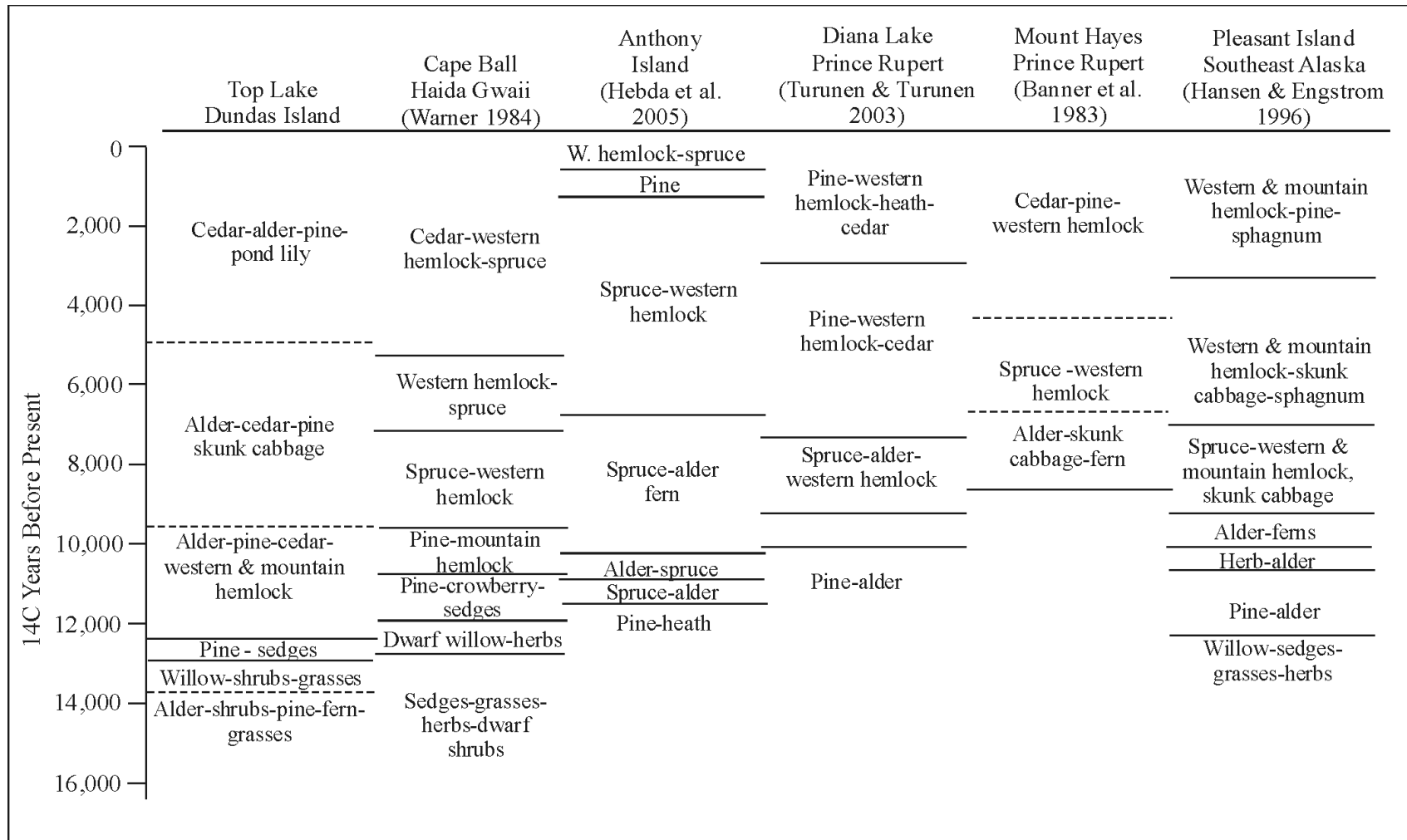
Figure 22. Cedar and pine forest in the vicinity of Top Lake.



Discussion

The sequence of vegetation communities reconstructed from the core taken from Top Lake is similar in some respects to that found in other areas of the north coast (Figure 23). Overall, this suggests climatic rather than local factors were the main causes

Figure 23. Comparison of regional vegetation histories for selected sites on the northern Northwest Coast. Major species are indicated, solid lines indicate dated transitions, dashed lines are inferred. Based on similar charts in Lacourse and Mathewes (2005) and Turunen and Turunen (2003).



of ecological changes, at least during the late Pleistocene and early Holocene. However, there are some unique aspects of the pollen assemblage that are likely due to the isolated geographic position of these islands in combination with localized climatic effects and succession.

Alder, pine, grass, and fern characterized the earliest ecological setting on Dundas Island, zone I. This combination of vegetation was similar to early ecological conditions found at several sites on the northern Northwest Coast beginning around 13,000 BP where shrub vegetation with pine were frequent (Fedje 1993; Hansen and Engstrom 1996). The earlier herb tundra ecosystem, found at Cape Ball, is not reflected in the assemblage from Dundas Island (Warner et al. 1984). By cross-referencing the Top Lake core to others on the coast, it is possible that zone I began sometime around 13,000 BP. However, zone I is followed by a tundra-like assemblage. There are no analogous sequences on the northern Northwest Coast that have a pre-12,385 BP date associated with them. It is possible that at least some of the pollen from the top of zone I is contaminated as a result of the coring method used, but the lowest samples are over 50 cm below the top of the core section suggesting that the assemblage is not the result of Livingstone core contamination. In consideration of this evidence it is likely that this zone predates 13,000 BP. Overall, the pollen concentration for this zone is extremely low relative to the amount of sediment examined suggesting that a low cover of vegetation was growing on the landscape and environmental conditions were periglacial.

The succeeding Zone II indicates a more tundra-like landscape occurred than the previous zone. Willow, sedges, grasses, and ferns dominated this vegetation zone. Overall the willow, sedge, and grasses formed a shrub tundra similar to those that

occurred at Cape Ball (Warner et al. 1984), Westside Pond (Fedje 1993) on Haida Gwaii, and Peasant Island in southeast Alaska (Hansen and Engstrom 1996). These tundras predated the pine dominated zone that appeared between 13,000 and 12,000 BP. At the top of this zone a shift in the sediments of the core from grey clay to brown organic silts occurs. This transition reveals an increase in the amount of organic material on the landscape that surrounded the lake. Zone II occurred before the date of 12,385 BP at Top Lake.

Zone III from Top Lake began sometime beginning 12,385 BP, and it is within this zone that pine suddenly became dominant. In other areas of the coast, this lodgepole pine dominated zone was typical, beginning between 13,000 and 12,000 BP (Hansen and Engstrom 1996; Hebda 2005; Heusser 1995; Warner et al. 1984). With the concurrent presence of shrub and herbaceous vegetation, it is likely that the environment was parkland-like. Unlike other areas on the northern Northwest Coast however, this zone ends abruptly sometime around 12,250 BP. This is possibly due to an unconformity or break in the sedimentary sequence at Top Lake at the top of the pine zone. Brown organic clay sediments indicate a change from a mineral based depositional regime to one that was dominated by biogenic deposition. Based on this observation it appears that the surface was increasingly stabilized by vegetation and associated with increased soil development.

Zone IV begins ~12,250 BP and was marked by an increase in alder, and a diminution of pine, shrubs, and herbaceous plants on the landscape. Conifer species, other than pine, began to increase. Coniferous species also began to establish at this time on Haida Gwaii, in particular, *Picea*, which differs from the Dundas Island assemblage

(Hebda et al. 2005). Shortly after the beginning of this zone, but before 10,565 BP, an increase in mountain hemlock pollen occurs. Similar patterns have been found elsewhere on the coast during the Younger Dryas cooling event (Mathewes 1993). However, the changes in vegetation as a result of this global cooling event are not so obvious in the Top Lake pollen assemblage and clustering using CONISS did not find enough variation to include this mountain hemlock spike as a separate pollen zone. The radiocarbon dates on the core between 12,250 and 10,565 BP are separated by only 11 cm; only one slide was counted from this interval. Again, an unconformity likely exists in the core sediments separating zone III and zone IV. As a result, most of the pollen counted for zone IV dates between 10,565 and 9,810 BP and the preceding (12,250-10,565 BP) pollen is not well represented.

A stratigraphic change from brown organic clay to organic rich gyttja occurs at the beginning of this zone suggesting that it took place in association with the growth of dense stabilizing vegetation. The appearance of these forests suggests warmer and wetter conditions occurred than previously. This zone is unique compared to other north coast sequences as spruce was present but remained at low frequencies in the early Holocene.

Zone V begins 9,810 BP and was similar to the preceding zone IV, with the exception that a marked increase in skunk cabbage and cedar pollen occurred. This change suggests effectively wetter environmental conditions existed combined with increased paludification of the landscape. Although alder declined slightly it was still the dominant taxon. Similar increases in wetland vegetation occurred between 9,000 and 6,000 BP in most places on the northern Northwest Coast (Banner et al. 1993; Heusser 1995; Hansen and Engstrom 1996; Turunen and Turunen 2003). However, unlike areas

in southeast Alaska and Haida Gwaii (Cwynar 1990; Fedje 1993; Hansen and Engstrom 1996; Heusser 1995; Warner 1984), *Picea* and *T. heterophylla* do not seem to have become as abundant on the Dundas Islands. From the Prince Rupert area, Banner et al.'s (1983) contemporaneous early Holocene assemblage, which was dominated by *Alnus* and *P. contorta*, dated to 8,700 BP. *Picea* and *T. heterophylla* were present in higher percentages than on the Dundas Islands landscape, and increased into the mid-Holocene. Significantly, the low abundance of these coniferous species on the Dundas Islands was regionally distinct.

Zone VI, beginning 5,090 BP is dominated by cedar, but abundant alder pollen remains. The zone represents the establishment of modern vegetation. The dominance of cedar during this period was likely related to the continued paludification of the landscape, making it difficult for arboreal species, with the exception of *P. contorta* and *C. nootkatensis*, to have become established in many areas. In addition, there was a coast-wide increase in the amount of *T. plicata* during the later Holocene (Hebda and Mathewes 1984) and this seems to have occurred on the Dundas Islands 5,000 BP. The pollen of this zone reflects the current cedar-pine forests that surround the peat bogs typical of inland areas on the Dundas Islands. This vegetation community is different from other areas of the northern Northwest Coast where pollen analyses have been undertaken. In particular, the continued low frequencies of *Picea* and *T. heterophylla* reflect this. This may be the result of the isolated location of the Dundas Islands combined with the prominent bedrock outcrops, shallow soils, low relief, flat topography, and saturated areas that surround Top Lake.

Conclusion

Marked ecological changes occurred on Dundas Island since the last glacial maximum. The pollen profile from Dundas Island reflects a pattern in which the late Pleistocene contained periods of abrupt climate changes that triggered ecological transformations. It is possible that human populations could have flourished during any of these periods, as did other mammalian populations, although the earliest habitats may have been scant. Furthermore, relatively abrupt ecological changes would have necessitated swift changes in human land use and settlement patterns.

Unlike the late Pleistocene, the Holocene is represented by relative stability in the pollen sequences from the northern Northwest Coast (Hebda and Whitlock 1997). While undoubtedly some climate change occurred during this period, the greatest change noted on Dundas Island was the increasing dominance of cedar forests and the expansion of bog ecosystems, both of which resulted from local and general climatic conditions and succession.

Overall, the pollen sequence from the Dundas Islands is similar to that from other areas on the northern Northwest Coast. Clearly, regional climatic variation during the late Pleistocene reflects a shift from late-glacial to temperate climatic conditions. The Holocene sequence on the Dundas Islands was unique in some respects. In particular, the abundance of several conifer pollen types, other than *P. contorta* and Cupressaceae (yellow and red cedar), remained low throughout the Holocene.

*Chapter VI - Dundas Island Archipelago Late Pleistocene and Holocene
Sea Level History*

Introduction

This chapter outlines the goals, methods, and results of research oriented towards identifying late Pleistocene and early Holocene shorelines on the Dundas Island Archipelago. This sea level research was the first step in providing geographic data from which the archaeological survey for late Pleistocene and early Holocene archaeological sites could be conducted. As the study area lies between two regions with differing sea level histories, the isostatically depressed mainland to the east and the forebulged Haida Gwaii to the west (Clague et al. 1982; Barrie and Conway 2002a; Hetherington 2002; Fedje et al. 2005b), it was hypothesized that the Dundas Islands region may have been hinge-like in respect to the isostatic and eustatic processes taking place. Fedje et al. (2004a) have suggested that this may be the case for much of the western margin of eastern Hecate Strait. On the basis of this hypothesis, the search for relict shorelines on the Dundas Islands was undertaken. As the study area is closer to the mainland than to the forebulged continental margin, it was predicted that relict shorelines would be slightly above present day shorelines. For this reason, most of the field methodology for this dissertation was undertaken in inland areas.

Methods

Field investigations carried out to collect data regarding former sea levels were undertaken in the summers of 2001, 2004, and 2005. Three approaches were used:

- i) identification of geomorphic features associated with past shorelines;

- ii) investigation and sampling of sediment sections; and
- iii) sampling sediments through lake basin coring.

An important aspect of all three methods was determining the elevation of features and samples. Due to the remote location of the study area and the lack of suitable bench marks, all elevation measurements were made relative to the highest elevation that barnacles are found in the intertidal zone. The barnacle line on the Dundas Islands is approximately 1.5 m above mean tide and elevations are referenced in metres above the barnacle line (abl). Following the work of Cannon (1999), the barnacle line was chosen, as it tends to vary less than the vegetation line. On average, we found that the barnacle line was 2 m below the vegetation line in most areas. The following subsection discusses the relevance and purpose of conducting these field investigations.

Methods for Identifying Geomorphic Features Associated with Past Shorelines

The types of features that are preserved in relation to relict shorelines depend on many local geographic factors (Jordan 2001). It was expected that relict shorelines on the Dundas Islands would reflect those categorized in the physical shore zone mapping system (Figure 24 and Table 8) produced for present day coastlines in the region (Howes et al. 1995).

Figure 24. Examples of beach substrates on Baron Island mapped from physical shore zone data.

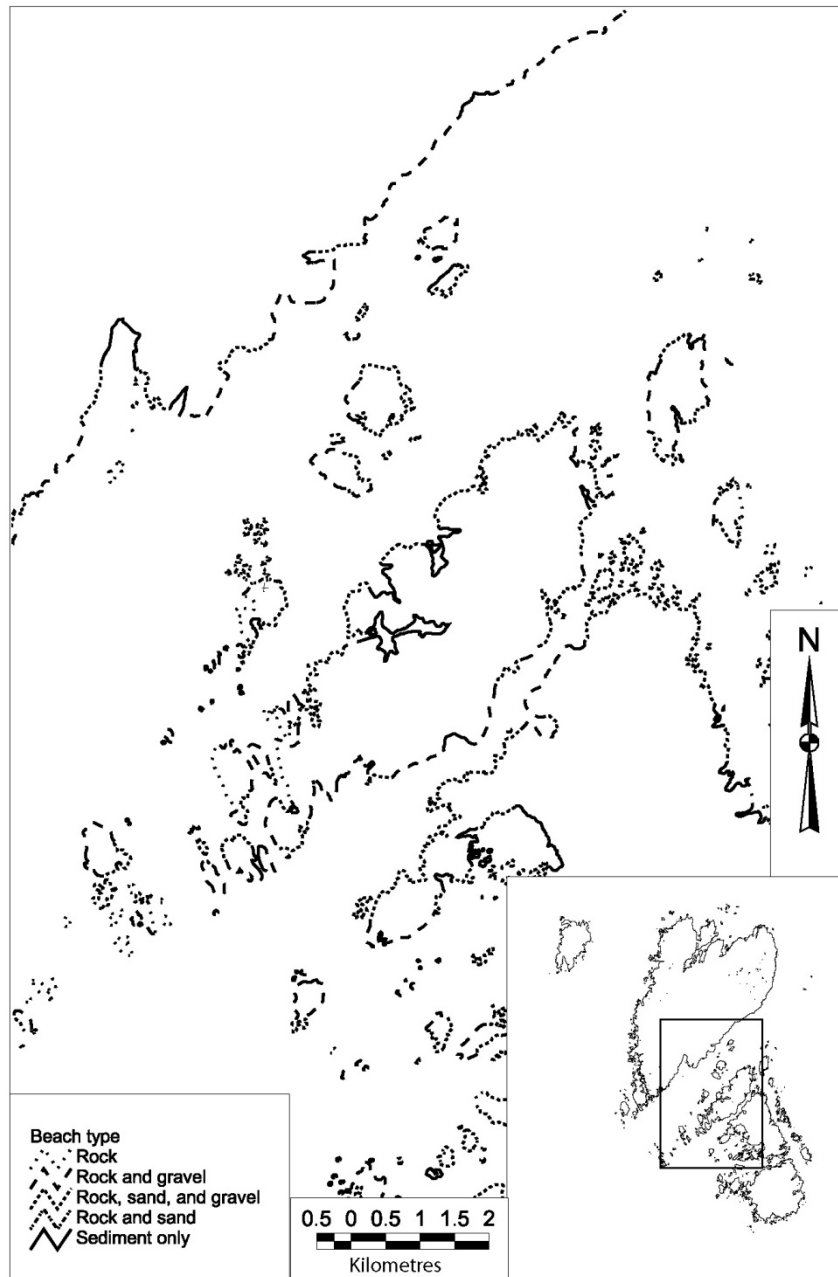


Table 8. Length of general physical shore types on the Dundas Islands calculated from the physical shore zone map database for the Dundas Islands. Based on typology described in Howes et al. (1995).

Length (m)	Shore Type
14817	Estuary, marsh or lagoon
1210	Gravel beach
774	Gravel channel
8146	Gravel flat
45422	Rock cliff
4623	Rock platform
143445	Rock with gravel beach
19776	Rock with sand beach
250448	Rock, sand and gravel beach
2152	Sand and gravel beach
124985	Sand beach
12804	Sand flat
1164	Unclassified
629766	Total shoreline inventoried

Under changing environmental conditions, it was also expected that shoreline formation processes have shifted since late Pleistocene times (Jordan 2001). It was anticipated that some relict shorelines in the area would be similar to those found in periglacial coasts with limited sediment supply, as are found at the mouth of the Skeena River (Clague et al. 1982). Visible erosional features characteristic of rocky shorelines were expected: cliffs, platforms, notches, and sea caves (Masselink and Hughes 2003). In other areas, wave-constructed sedimentary forms such as spits, bars, tombolos, beaches, or berms were expected. Aeolian processes may have been more active in earlier time periods as transporters of sediments, resulting in the construction of dune features.

For the purpose of this study, ground-based surveys in the form of inland traverses were undertaken to locate and map the elevation of topographic features suspected of being created by higher sea levels. Areas were chosen for survey after studying physical shore zone maps, aerial photographs, BC Terrain Resource Information Management (TRIM) maps, and marine charts. Surveys were undertaken on foot. Where notable features were found, their locations were mapped using Garmin digital altimeter

and Garmin GPS and/or using a clinometer, hipchain, and compass. GPS accuracy depended on the amount of forest canopy and time of day but was generally +/- 6 m. In general, GPS elevations were not relied upon, rather an altimeter was used. Often several readings were recorded using the altimeter and the mean of the combined measurements calculated. In addition, compass and clinometer transects were plotted to check elevations of significant features. Inland surveys were also targeted in areas with limestone for the purpose of identifying caves and features associated with limestone coastlines such as notches and shelters.

Where it was suspected that sedimentary landforms underlie soils and overburden, a 5 cm diameter Dutch auger was used to determine the nature of the underlying accumulations. In some instances sampling was undertaken using an environmental soil probe (ESP) coring device, which is a percussion-coring implement that recovers sediments in a 2 cm diameter clear plastic tube.

The identification and measurement of geomorphologic features can indicate the elevation of past shorelines. These methods are also useful in identifying locations and places with preserved sedimentary landforms where archaeological deposits might be located. However, these methods used alone cannot provide insights into the timing of past transgressions. For this reason, sediment sections were actively sought, and isolated lake basins were cored.

Methods Used to Locate and Sample Sediment Sections

Surveys of select parts of the study area were undertaken to search for sediment sections. The primary method was to survey in areas with high potential for erosion, such as the valleys of fast-flowing creeks and rivers. Sections found were prepared using

shovels and trowels to clean up and better expose the stratigraphic profile. Vertical profiles were logged and photographed where they were suspected of providing evidence of raised relative sea levels. The elevation and location of each vertical profile were measured using a Garmin GPS and altimeter, and by using a compass, clinometer, and hip-chain.

Exposed sediment sections allow for detailed infield analyses of sedimentary units and transitions. Field notes were maintained to record these features. Sediment samples were taken for laboratory analysis by excavating and collecting material by trowel, and bagging and labelling each section of the column.

Methods for Coring Isolated Lake Basins

Based on TRIM maps and aerial photographs, lakes of different elevation were chosen for coring. Preliminary surveys were undertaken to measure the elevation of the lakes with an altimeter. Coring gear, including two canoes, a plywood platform, a coring device, and core boxes, were then packed into the lakes on foot. The two canoes were lashed together and tethered at three points to the shoreline to stabilize them above the desired coring location. The plywood was then placed across the gunwales of both canoes forming a stable coring platform. A large hole cut into the plywood enabled the coring to commence from the platform.

Two different coring methods were employed. In 2001, samples were collected using a Livingstone piston corer with a 100 cm long core barrel and 5 cm diameter. The coring crew pushed the device into lake-bottom sediments. Once the device had descended 100 cm into the sediments it was removed and the sample extruded into a core box. The Livingstone corer was then replaced in the sample hole and pushed to the same

depth that was previously reached and the next sample taken. As described in “Chapter V – Dundas Island Archipelago Vegetation History as Reconstructed through Pollen Analysis”, this method has obvious limitations as the corer often picks up sediment from the side of the core hole as it is reinserted and the piston drives it downward. This can result in the mixing of recent and older sediments in particular at the top of each sample.

In the 2005 field season, a percussion coring method was used to collect additional lake cores. In addition to the canoes and plywood, a ladder, sledgehammer, long sections of PVC and ABS pipe were used. Once the platform was set up on the tethered canoes, a folding ladder was erected on the platform. A PVC or ABS tube was then placed in the hole down to the lake bottom. A member of the coring crew then climbed to the top of the ladder to begin sledge-hammering the tube into the sediments at the bottom of the lake. If more length was needed, a pipe connector was glued to the end of the tube, and a new section added. A come-along, attached to the ladder, was then used to retrieve the core tube once the bottom of sediments was reached. There are limitations using this method of coring, in that sediments become compacted in the tube. It is difficult to assess the amount of compaction of different sediments that are picked up by the coring device. However, unlike the sectioned cores recovered using the Livingstone corer, there is a benefit in the percussion method as only one single long section of sediments is removed, which reduces the chance of mixing and contamination.

Detailed records and photographs of the methods used were maintained in the field. The elevations of all lakes that were cored were then measured using a Garmin altimeter, and through clinometer, compass, and hip chain survey. All cores were logged and carefully transported back to the lab by canoe, foot, motorboat, and motor vehicle.

Samples collected in 2001 were stored in a walk-in refrigerator at the Pacific Geoscience Centre in Sidney. In 2005 all samples were transported to the archaeological labs at the University of Victoria where they were placed in cold storage, a chest freezer that was converted into a refrigerator.

Laboratory Analysis

Once data and samples were recovered from the field, laboratory analysis was undertaken to provide an understanding of past geological and environmental conditions of the field locality. To reconstruct past sea levels, work undertaken in the laboratory can accurately and reliably define between marine and non-marine environments, the chronology of sedimentary deposition, and characteristics of past environmental conditions. The following section is a discussion of the lithological, biogenic, and radiometric analyses that were used to address the goal of reconstructing the sea level history of the Dundas Islands.

Lithological Analysis

In the lab, percussion cores were split using a jig and saw to cut the outer plastic tubing, and a knife to cut the cores in half. All percussion and Livingstone core sections were cleaned for core logging by scraping the sediment faces. All sections were measured and a qualitative description of sediment colour and grain size was made. All significant transitions in colour and grain size were noted. Major transitions were of particular importance as they are the result of changes in facies. However, from core logging and sediments analysis alone it is not always possible to determine if the transition is the result of shifting sea levels or a change in other environmental conditions.

In one instance marine shells were found in the sandy sediments of a core indicating marine or intertidal sediments. In cores lacking this type of macrofossil evidence, 1 cm³ samples of sediments were taken during core logging for the purpose of conducting diatom analysis. The depth of each sample was recorded.

Sea Level Analysis Using Biological Proxies

Diatom analysis is particularly well suited to the identification of local habitat change, in particular, shifts in salinity. For this reason, diatoms have frequently been used to provide insights into sea level changes (Pienitz et al. 2003). Diatoms are single celled members of the Algae Kingdom. Different species survive in different water conditions and can be distinguished from one another on the basis of various morphological characteristics. Diatoms are very common in both salt and fresh water, and their siliceous valves often preserve well. The types of species that thrive in a given environment are well-known, described, photographed, and illustrated, aiding identification through comparison (e.g., Campeau 1999; Fallu et al. 2000; Pienitz et al. 2003). By comparing the types of diatom remains associated with shifts in lithological character, it is possible to characterize changes in salinity and infer whether stratigraphic changes are associated with changes in sea level. In some instances, sediments from lake cores may have significant lithological changes but lack changes in diatom species or inferred salinities, suggesting the sequence of events is not the result of shifting sea level.

Sediments from isolated lake basins were prepared for diatom analysis with a specific focus on depths where sedimentary transitions occurred. Sample and slide preparation followed the methods outlined by Battarbee (1986). In the case of organic sediments, 1 cm³ samples were placed in glass beakers. A solution of 30% H₂O₂ was

then added and the mixture heated for 1/2 hour at 90 degrees Celsius. The solution was then removed from the hot plate and allowed to cool. The samples were then agitated and left to sit for 1 minute, then decanted to centrifuge vials, leaving the coarse fraction in the base of the beaker. Distilled water was added and samples were spun in the centrifuge at 1200 rpm for 4 minutes. The supernatant was then decanted and the pellet re-suspended in distilled water. In this way the samples were rinsed three times.

Two methods were employed with samples that were rich in clay particles. Some samples were screened through a 10 μ mesh to remove the smaller clay fraction. Other samples were placed in distilled water, agitated, and then left to sit for two hours. After this the water and suspended particles were decanted and then the remainder was re-suspended for two hours. This process was repeated until all the clay particles suspended after the two hour period had been decanted. Slides were prepared by placing a small amount of the natant on a slide cover, which was left to air dry. The sample was then mounted on a frost sided glass slide.

Diatom identification and counting was done with a biological compound microscope. To identify different diatoms and their habitat, the following guides were used: Campeau et al. (1999), Fallu et al. (2000), Pienitz et al. (2003), and van der Werff and Huls (1956-1974). A preliminary evaluation of slides was made to determine if diatoms appeared to be of fresh water or marine origin. Slides from nine different lake cores were examined in this manner. In areas where sedimentary or biological transitions were found, a detailed analysis of diatom types was undertaken by counting 300 diatoms per slide, where possible. Thirty-seven slides were counted in detail for samples collected from four lakes at different elevations (Appendix B – Percentage of Diatom

Taxa per Sample Examined and Salinity.). In some cases, the diatom frequency encountered was very low. Where this occurred, as many diatoms as possible were counted on a minimum of four prepared slides.

The methods of diatom analysis were learned as a part of this dissertation project. I had support and guidance in the identification process. Daryl Fedje of Parks Canada, guided me in my earliest diatom identifications. Additionally, the first slides that I counted alone were returned to at a later date and questionable identifications were verified.

The analysis of biological samples can provide key insights in tracing marine transgression and regression. Combined with the lithological analysis, environmental changes can be identified through careful analysis. However, to create an understandable sequence of past events it is necessary that transformations be dated.

Radiometric Analysis

By comparing the types of diatom remains at different depths below the surface it was possible to characterize stratigraphic changes in salinity and ascertain whether such changes are associated with a sea level regression or transgression. Where major sedimentary transitions were found, AMS samples were chosen and sent to Lawrence Livermore National Laboratory's Center for Accelerator Mass Spectrometry in California (CAMS) and W.M. Keck Carbon Cycle Accelerator Mass Spectrometry Laboratory, also in California (UCIAMS). Where possible, radiocarbon samples were run on annually produced plant macrofossils such as seeds, cones, or leaves. In some cases, multiple macrofossils were picked per sample to provide enough carbon for an AMS date, but jeopardizing the potential accuracy of the resulting date.

Results

The following section summarizes the field results from creek survey, landform survey and testing, and lake coring. Figure 25 shows the locations of all data gathering locations visited during field work. A total of 11 AMS radiocarbon dates were obtained to aid in reconstructing the sea level history of the Dundas Islands (Table 9).

Creek Survey

Creek beds were examined for exposures (Figure 26 and Figure 27). Swift and fast moving creeks were preferentially selected for survey as it was hoped that the flow regimes of these types of creeks would be best for eroding surficial sediments. Abrupt elevation change in the topography surrounding the surveyed creeks was also noted as it was suspected that these may represent wave cut features or terraces. Creek traverses were also undertaken to search for karst caves in areas mapped as having massive homogeneous limestone by Hutchison (1982). In general, the creeks walked were found to be flat with gravel streambeds to about 6 m abl. At around the 6 m abl elevation, abrupt elevation changes were noted in several of the creeks.

Exposures were uncommon in the creeks surveyed. One good exposure of sediments was located during the “South Dundas 2” creek survey (see Figure 28). This exposure is located 3.91 m abl and revealed 260 cm of sediments. Overall the sedimentary sequence included a number of gravelly layers and two laminated sand layers near the centre of the profile. A fining upwards or downwards sequence could not be discerned. Careful examination of the exposure for shell macrofossils was undertaken as was the creek bed below the exposure, but none were found. Overall the sediment

Table 9. Radiocarbon dates used to reconstruct sea level history on the Dundas Island Archipelago.

AMS lab #	Sample location	Sample (cm dbs)	Lab or field depth	Surface sample (m abl)	Sample sill or abl (m)	¹⁴ C age	+/-	Material	Proxy indicators	Comment
UCIAMS 21986	WB	51	L	4	3.5	3,885	20	Wood	Basal peat	ESP core sample.
UCIAMS 23807	SH Lake	73	L	6.25	6.25	5,280	100	Seeds, insect part, needle fragments	Brackish diatoms	Lake core on SW Dundas Island near Edith Harbour.
CAMS 82216	BP Lake	214	F	6.5	6.5	8,000	300	Plant macrofossil	Brackish diatoms	Lake core. Large standard deviation indicates possible laboratory or sample contamination or low amount of carbon
CAMS 82217	BP Lake	505	F	6.5	6.5	9,735	40	Plant macrofossil	Marine diatoms	Bog core on SW Dundas Island near Edith Harbour.
UCIAMS 24510	SED Lake	270	L	10.25	10.25	10,320	40	Leaf and needles	Brackish diatoms	Lake core on western Baron Island.
UCIAMS 31733	TL Lake	543	F	33	33	10,565	50	Pine needles	Pollen core and fresh water diatoms	Bog core on SW Dundas Island near Edith Harbour.
CAMS 82220	SW Lake	220	F	13.5	13.5	12,135	40	Plant Macrofossil	Brackish diatoms	Lake core on SW Dundas Island near Edith Harbour.

AMS lab #	Sample location	Sample (cm dbs)	Lab or field depth	Surface sample (m abl)	Sample sill or abl (m)	¹⁴ C age	+/-	Material	Proxy indicators	Comment
UCIAMS 24508	SB Bog	174	L	13	13	12,170	160	Moss and seeds	Brackish diatoms	Bog core on SW Dundas Island near Edith Harbour.
UCIAMS 30933	TL Lake	555	F	33	33	12,250	50	Pine needles	Pollen core and fresh water diatoms	Lake core on SW Dundas Island near Edith Harbour.
UCIAMS 24509	S-Less Lake	170	F	16.25	16.25	12,385	30	Seeds and pine needle	Fresh water diatoms	Lake core on western Baron Island.
UCIAMS 31734	TL Lake	561	F	33	33	12,385	30	Seed	Pollen core and fresh water diatoms	Lake core on SW Dundas Island near Edith Harbour.

Figure 25. Palaeo-environmental data gathering locations visited during fieldwork.

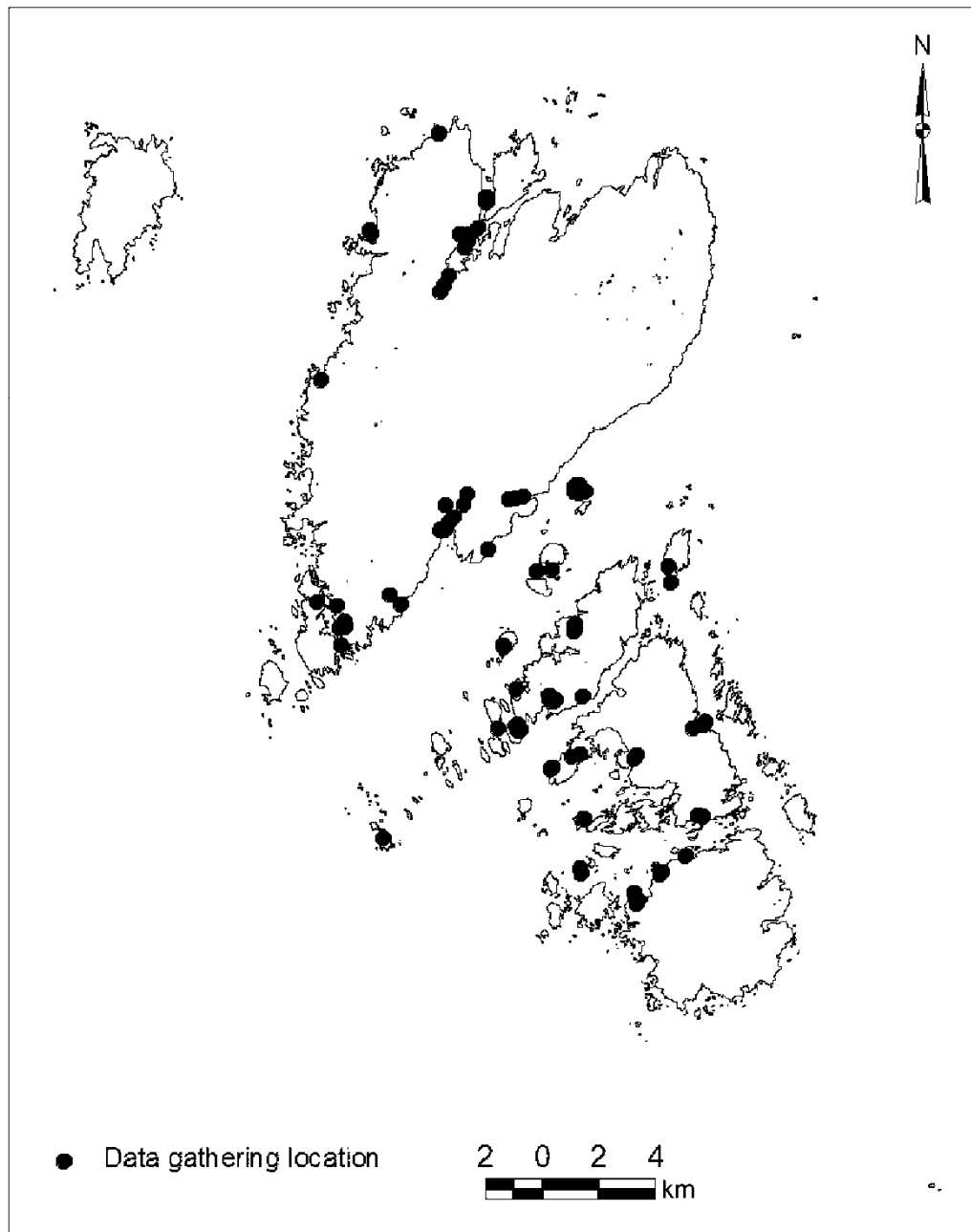


Figure 26. Creeks traversed on Dundas, Baron, and Dunira Islands.

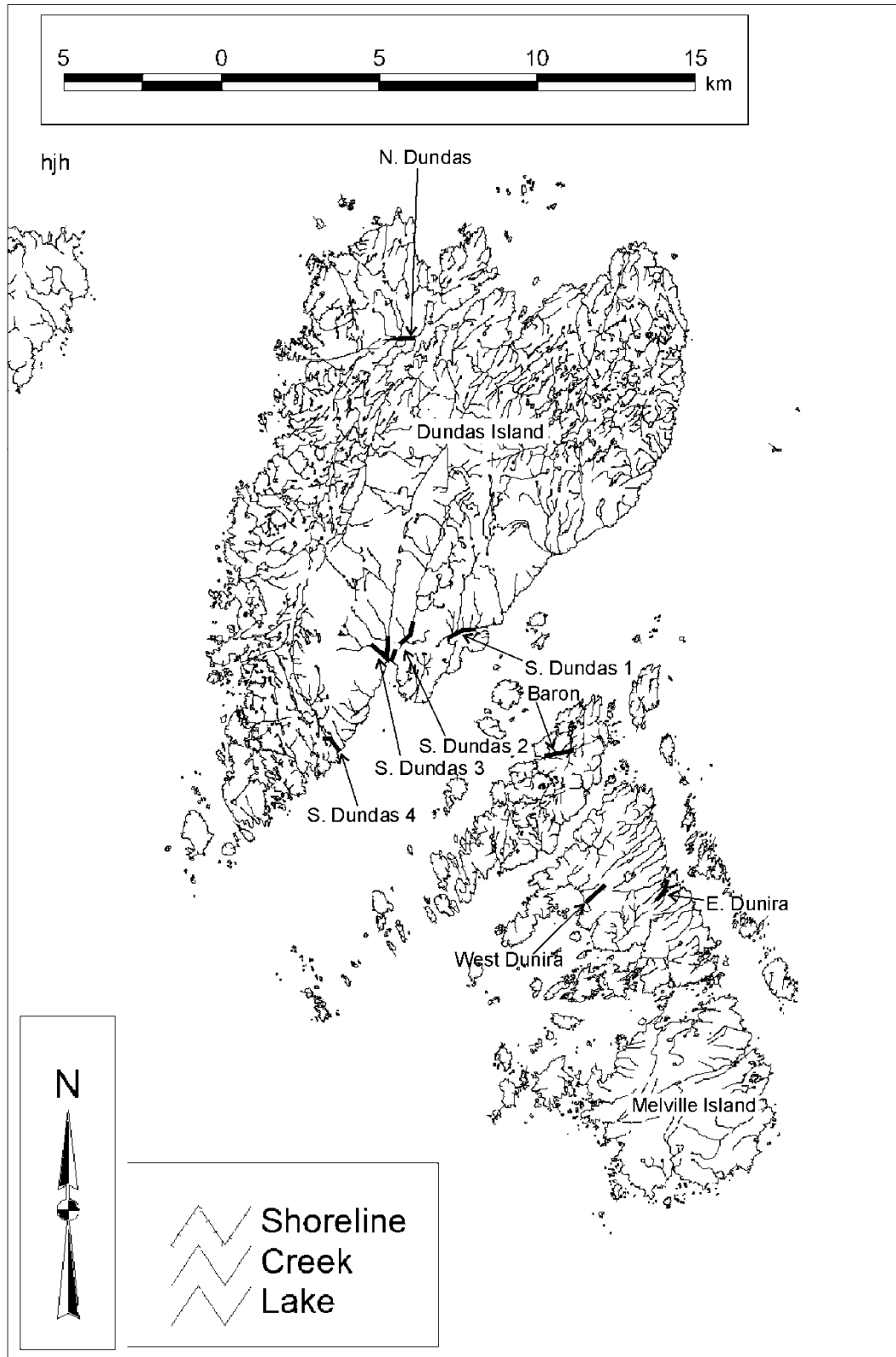
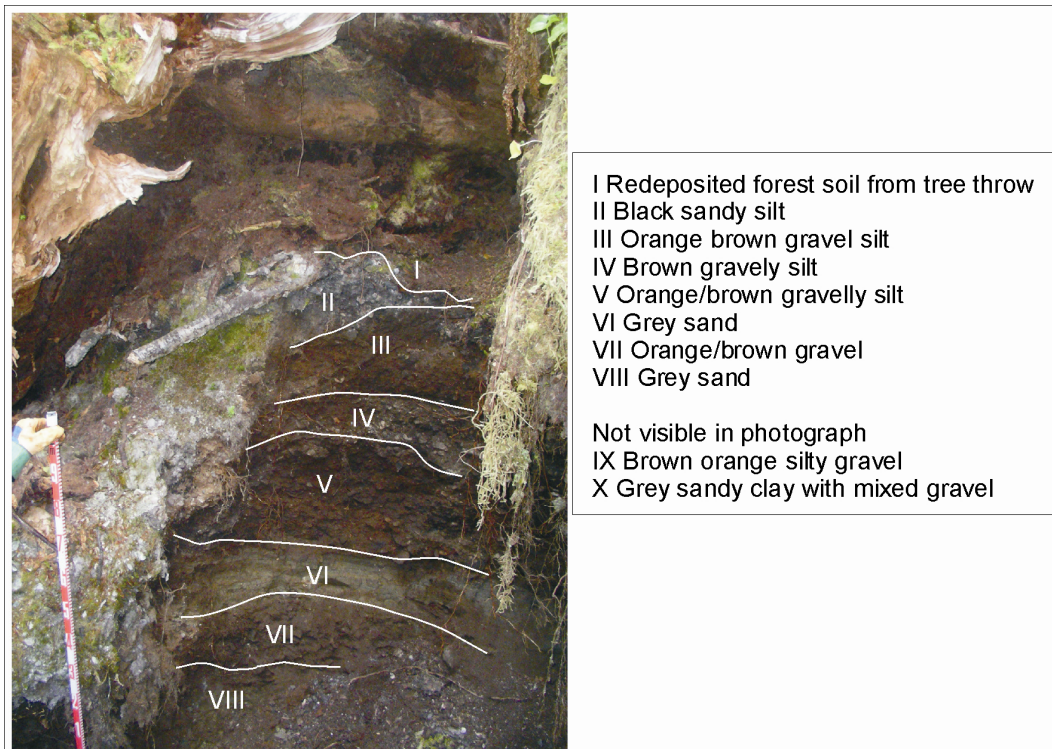


Figure 27. Creek survey on south side of Dundas Island.



Figure 28. Profile of exposure located on the south side of Dundas Island.



section was more reminiscent of a similar looking sedimentary feature, a storm beach bar, noted just above the upper intertidal zone at the mouth of the same creek.

On the north side of Dundas Island and the east side of Dunira Island, Hutchison (1982) mapped areas of massive limestone during a geological survey. We returned to these areas and identified limestone in the intertidal zone where Hutchison had also found it (Figure 29). Creeks were chosen for surveys in both of these areas to locate karst features. In both instances it was found that the limestone occurred in the intertidal zone but did not continue up the chosen creek beds. Areas close to the shoreline and adjacent to the creeks were also surveyed. However, the thick canopy and lack of well developed karst features rendered this approach in these areas ineffective for locating caves.

Figure 29. Limestone on east side of Dunira Island.



Geomorphic Features

Surveys for geomorphic features associated with raised shorelines focussed on types that would be highly visible on maps, aerial photographs, and on the ground through tree canopies and underbrush. Two general feature types were actively sought and recorded: those associated with rocky shores and those constructed from sediments.

Rock Shorelines

By examining 1:20,000 scale maps with 20 m contours from the western side of Dundas Island, Baron Island, and Melville Island, it is discernable that the 20 m contour is very close to the shoreline. The 40 m contour tends to be a far greater distance from the 20 m contour than the 20 m contour is from the shoreline. This indicates that below 20 m there is a greater slope than there is between 20 and 40 m. Overall this steepening of slope may be the result of the erosion of the rocky shoreline during Pleistocene sea level fluctuations. This change in slope results in a change of ecosystem as well, with the steep and better-drained coastal fringe vegetated by coniferous forest and the inland and flatter areas above 20 m being vegetated by peat and pine bogs. This transition in vegetation type is clearly visible from aerial photographs (Figure 30). Field inspections of the slope break found it to lie between 20 and 24 m abl.

When traversing forested areas of the Dundas Islands, the elevations of abrupt changes in slope to 20 m abl were recorded. An example of abrupt change in slope is a cliff face rising from a flat forested area. As cliffs and ramps can be plucked and shaped in the intertidal zone, recording these types of features may provide information about the elevation of relict shorelines. However, cliff and topographic changes can also be created by tectonics or by other erosional processes. As a raised shoreline is a long linear feature,

it was hypothesized that where cliff features resulting from wave plucking and intertidal erosion occur, there should be repetition in elevation of these features as they result from a linear erosional process.

Slope breaks at 6 m abl were the most commonly found in the study area (Figure 31). Many of the features recorded during survey were slope changes on the most northerly of the Nares Islets. However, abrupt elevation changes were noted in other areas and have been included in this exercise. Slope breaks were also noted at higher elevations, but not with the same clustering as at 6 m.

Other common features of rocky shorelines are wave-cut notches. These features are more typical in areas with limestone coasts. We located a feature similar to a wave cut notch in a granitic-quartz-diorite cliff face in Edith Harbour (Figure 32). The large crystalline structure of this cliff face is loosely consolidated and the notch appeared to follow a line of structural weakness. The elevation of the feature was measured to 6 m abl. Although other cliff faces were examined for wave cut notches, no other clear examples were located. The elevation of this Edith Harbour notch provides additional evidence of a linear pattern of eroded features at 6 m abl.

Figure 30. Detail of aerial photograph (BC77008 #46) from the NE side of Dundas Island demonstrating the shift from steep well-drained areas of the coastal fringe and the flatter boggy areas above 20 m.

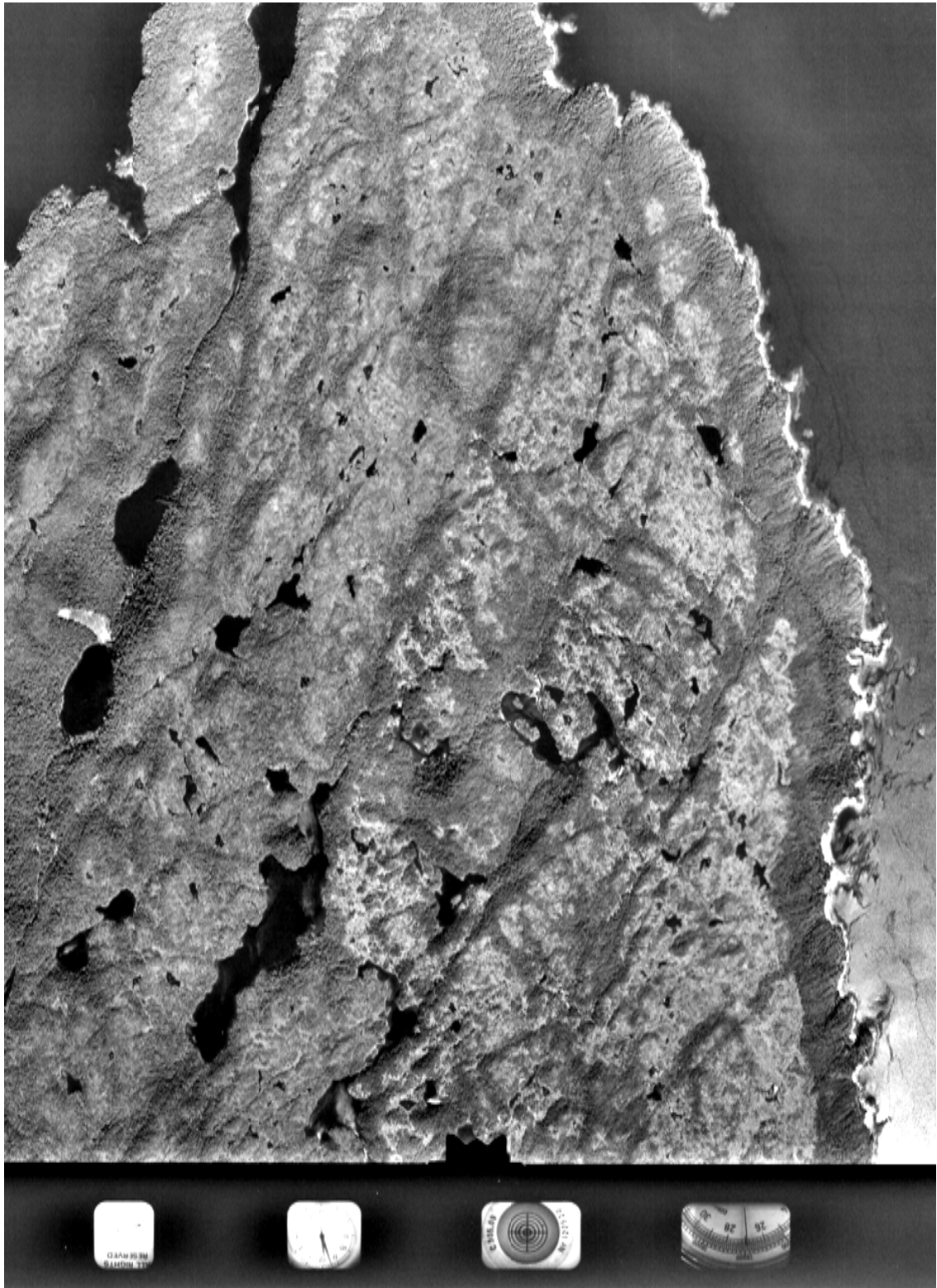


Figure 31. Elevations where abrupt change in elevation was noted during survey (all measurements rounded to the nearest metre).

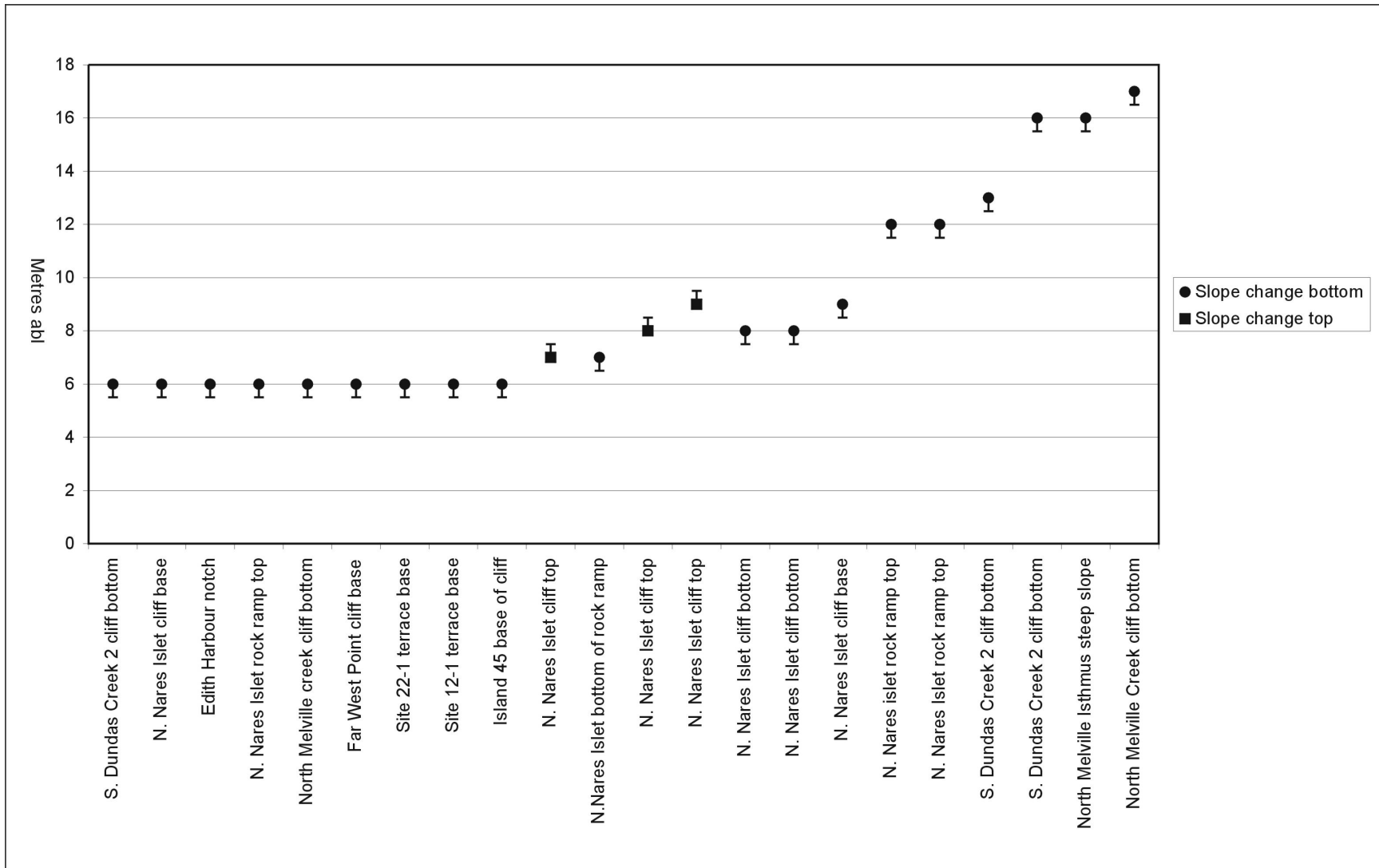


Figure 32. Wave cut notch located 6 m abl above shoreline of Edith Harbour.



Overall the investigation of rocky shoreline geomorphic features added to the general knowledge of sea level histories in the Dundas Island Archipelago. The erosional effects of past sea level stands on the rocky shoreline of the Dundas Islands have created features between present-day sea level and 24 m abl. A cluster of elevated eroded features occurs at 6 m abl suggesting the possibility of a relatively stable shoreline at this elevation at some time in the past.

Sedimentary Features

As indicated by the physical shore zone map data acquired for this field research, sedimentary features tend to be associated with low relief and protected areas. For field-based investigations this posed some logistical constraints. Investigating elevated landforms in flatter areas may involve traversing significant horizontal distance. Indeed, a creek traverse conducted on Baron Island failed to reach an elevation of 5 m abl after hiking inland for two hours. Also, flat areas tend to be covered with a thick blanket of peat, rendering many features indiscernible or difficult to investigate.

Some sedimentary features are common in areas of steeper slope, and if there is enough protection from erosion, they can be preserved. From marine charts and physical shore zone maps it is clear that tombolos and delta fans occur within the current intertidal zone on the steep rocky dominated west sides of the Dundas, Baron, and Dunira Islands, and the north side of Melville Island. The likelihood that similar relict features may have existed but now lie inland of the present-day shoreline can be predicted, to some degree, from map data. In particular, relict tombolos may appear as present-day low isthmuses. Remnants of ancient delta fans may be associated with present-day drainages. During our field research these features, in particular isthmuses, were targeted to gather data on the genesis of sedimentary landforms. Preliminary inspection of isthmus features occurred on the north side of Dundas Island, the Nares Islets, the west side of Baron Island, the Connel Islands, and the north side of Melville Island.

On the north side of Melville Island, a notable exposure was found. This exposure is located on the west side of an isthmus that connects Melville Island to a small rocky islet to the north (Figure 33). A small creek has cut a gully into the sedimentary feature that connects these two islands. The exposure is 6 m high stretching from 4 m abl to 10 m abl

(Figure 34). The sedimentary exposure reveals a coarsening upwards sequence with an interbedded sand and silt unit capped by a gravel dominated unit. Overlying the gravel unit are gleyed soils with some charcoal concentrations. This charcoal may have resulted from natural or cultural agents. The gravel unit is located between 6 and 8 m abl. Overall the sediments of the exposure found on the north side of Melville Island mirror the sediments found in the intertidal zone directly below. Below the barnacle line, sediments in the intertidal zone are silty with no visible clasts. Between the barnacle line and the vegetation line, gravel and cobble are dominant, most being derived from the creek and deposited in the upper intertidal zone where the steepness of the creek meets the flatter and often inundated intertidal zone. The murky colour of the water in this bay compared to the clear flowing creek suggests that much of the silt in the lower intertidal zone is marine-derived. By extension, the basal sandy sediments of the north Melville exposure reveal a low intertidal or subtidal accumulation of marine suspended sediments. With regressing sea levels, the top of the feature emerged into the upper intertidal, where creek based sediments were introduced, thus accounting for the large fraction of the gravel-dominated unit in the upper exposure. As with the measurement of rocky shoreline feature elevations, this sedimentary record points to the occurrence of an intertidal zone at, and slightly above, 6 m abl. A gravel dominated stratum in the lower sand unit of the profile suggests the possibility of an oscillation in the shoreline from low intertidal to high intertidal and back again. Sediments in this exposure were carefully examined for evidence of shell macrofossils but none were found. Couplets noted in the lower sand units may be the result of seasonal differences in the suspension of sand by the marine waters of the region, and/or a shift in stream versus ocean-borne deposits.

Figure 33. Location of sedimentary exposure found on the north side of Melville Island.

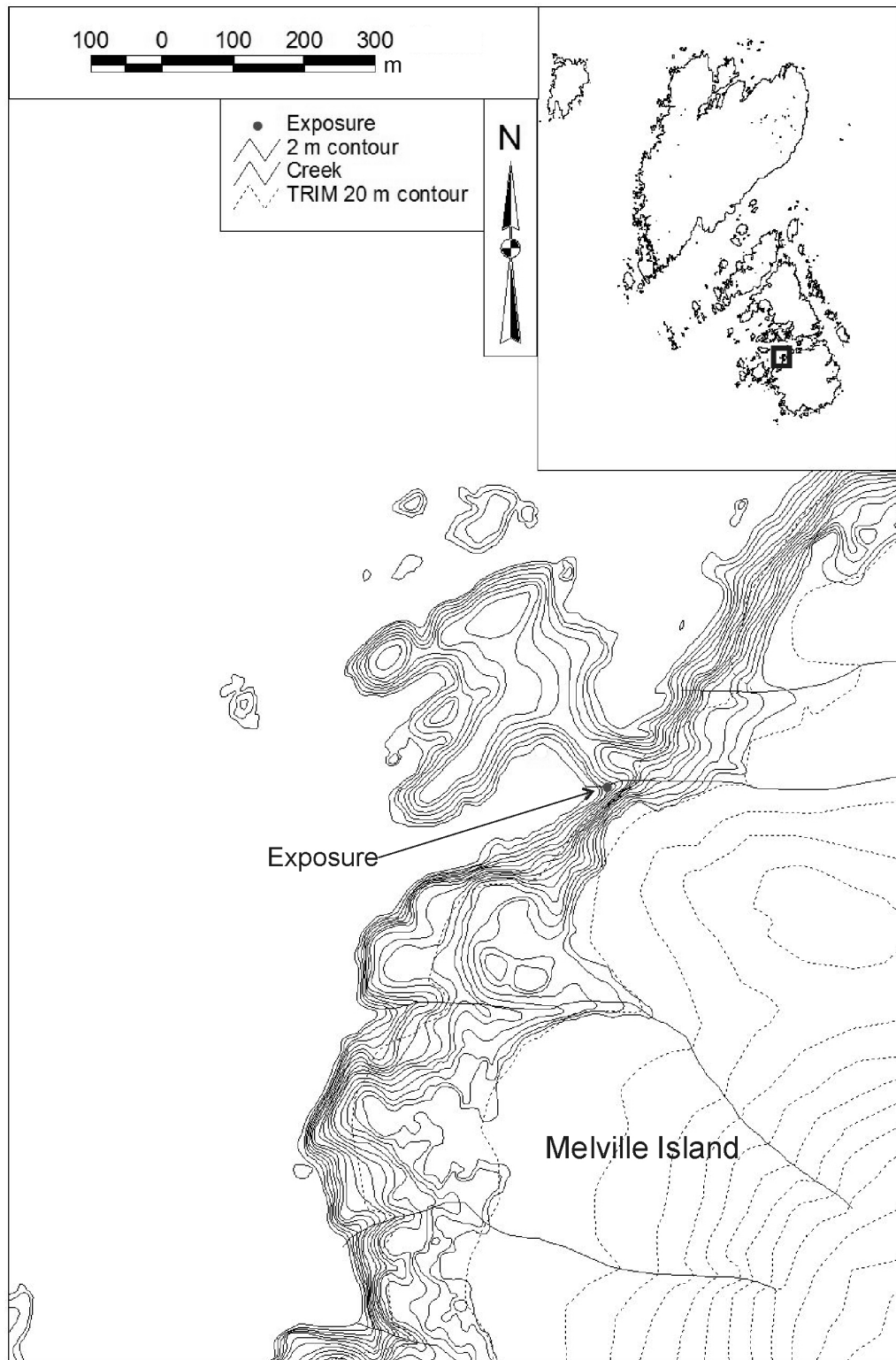
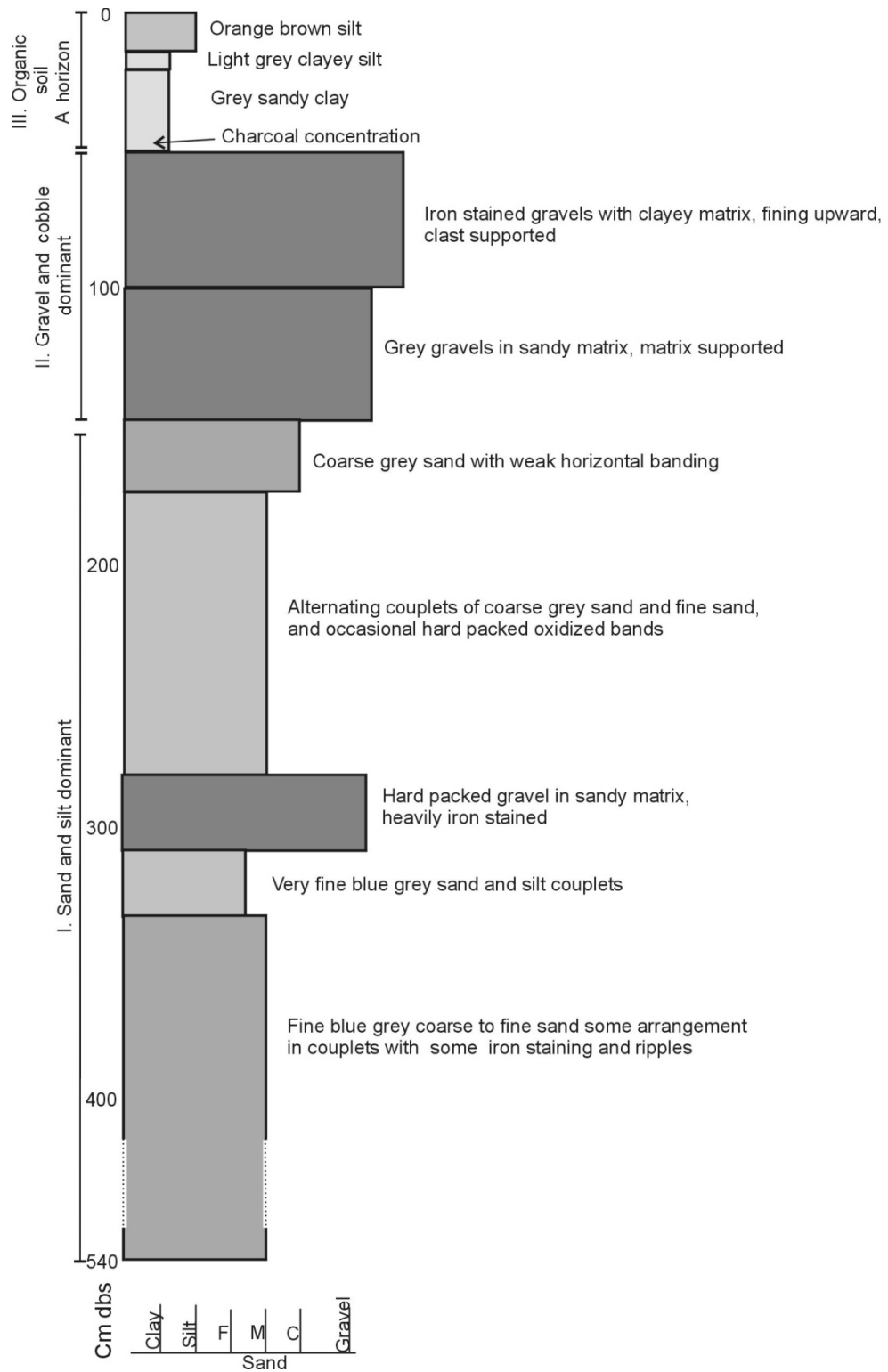


Figure 34. Sedimentary profile at the north Melville Isthmus



Sedimentary deposits with similar characteristics have been found up to 17 m abl in subsequent subsurface auger and shovel testing of the north Melville Isthmus. This testing is discussed in more detail in “Chapter VIII – Archaeological Prospection Undertaken on Raised Marine Landforms on the Dundas Island Archipelago”.

Exposures were not found during surveys of other isthmus features. However, with the use of probe and auger tools some insights into the underlying sediments could be gained. Systematic auger testing at different elevations was undertaken at two isthmus features: one located on the north end of Dundas Island (Figure 35) and the other on the western side of Baron Island (Figure 36).

The isthmus feature at the north end of Dundas Island rose from the intertidal to 9 m abl. Auger tests were undertaken onto the sides of the isthmus so as to avoid the thick peat blanket located at the centre and flatter part of the feature. Sands were found to underlie peat deposits in tests that were not stopped by roots between 2 and 9 m abl, revealing the likelihood that this isthmus is the remnant of a raised tombolo which began to be formed when sea levels were 9 m higher than today.

The isthmus at the west end of Baron Island was tested using augers and by ESP corer. This feature rises to 12 m abl. Auger testing undertaken above the vegetation line found blue-grey clay below peaty soils between 4 and 6 m abl and sands or gravels between 6 and 10 m abl. Clasts stopped the two tests undertaken between 10 and 12 m abl and as a result the subsoil substrate remains unknown.

Figure 35. Auger test locations conducted at different elevations on the isthmus that separates Goose Harbour from Brundige Inlet on the north side of Dundas Island.

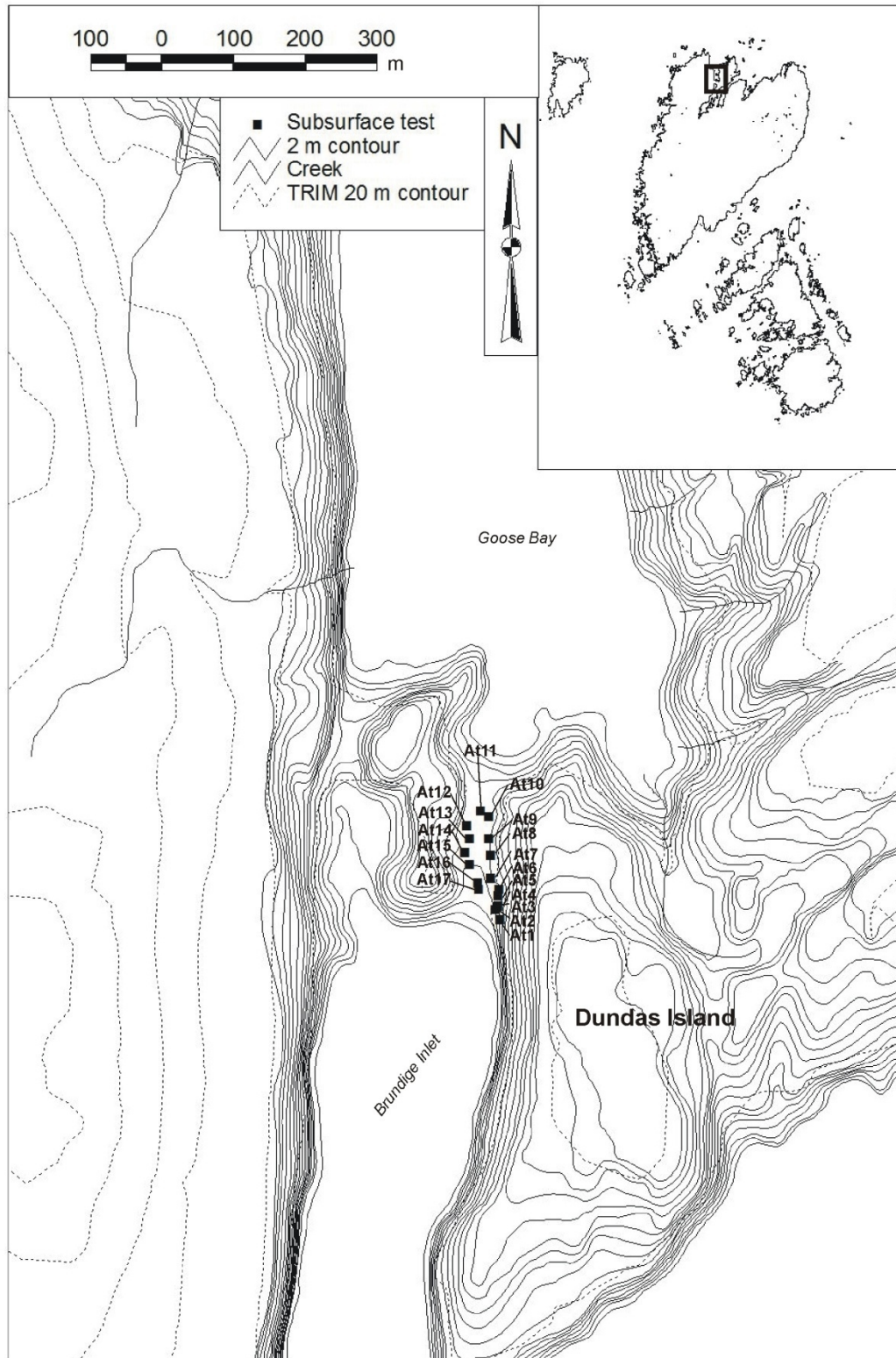
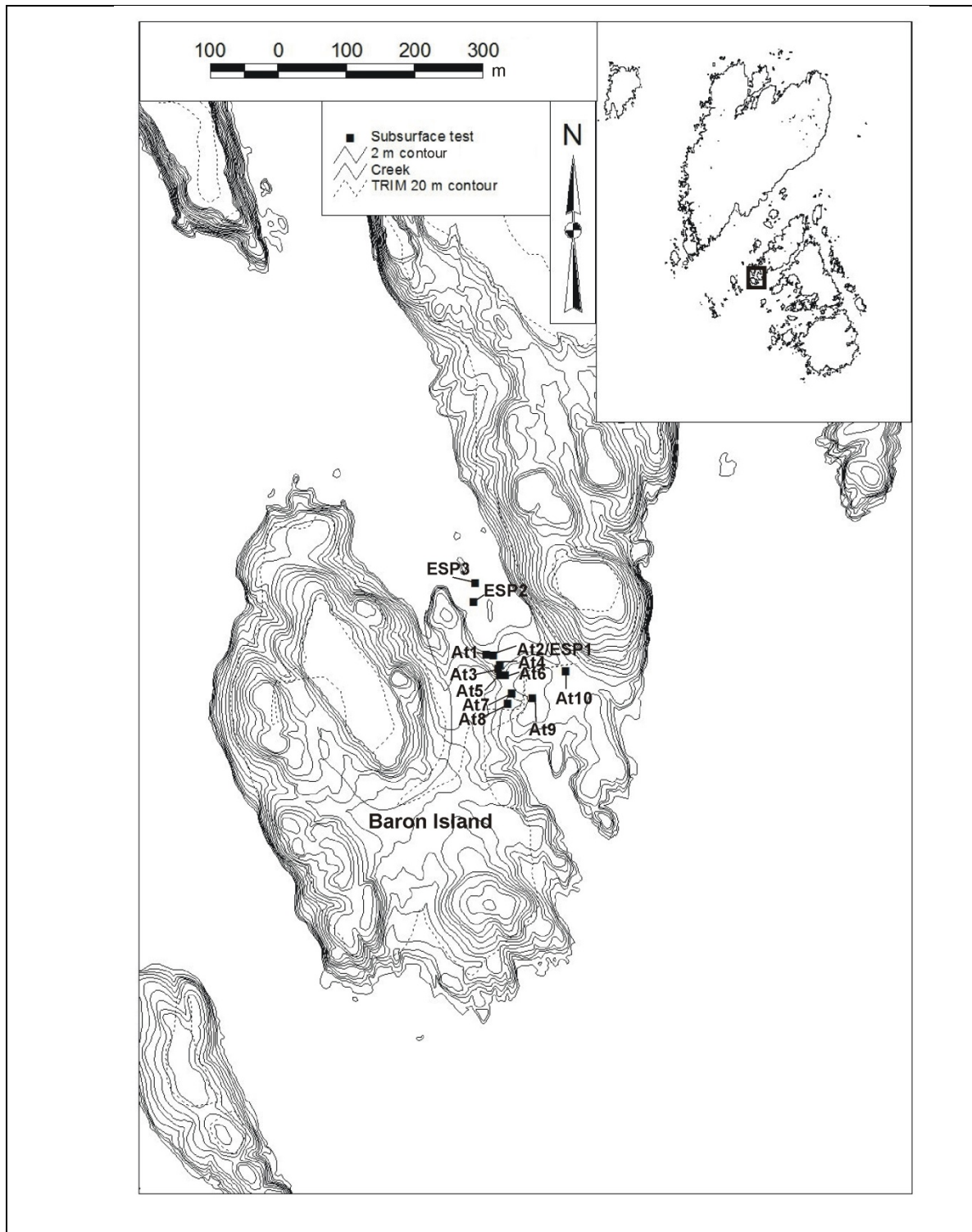


Figure 36. Auger test locations conducted at different elevations on the isthmus located on the west side of Baron Island.



Three ESP core tests were undertaken in order to sample sediments from the isthmus area at the western end of Baron Island. The first test was placed adjacent to an auger test undertaken at 4 m abl. In this test a transition from peaty soils to bluish marine clays was recovered. A small piece of wood lying on the clay to peat transition was selected as a radiocarbon sample and sent for dating. A date of 3,880±20 (UCIAMS 21986) was returned revealing that at this time peat developed on the clay landform.

Two additional ESP core tests were undertaken at this location, one at 1 m below the barnacle line, and the other 3 m below the barnacle line. These tests were undertaken to determine if terrestrial peat underlay the marine silts and clays exposed on the surface of the intertidal zone. The tests reached depths of 276 and 184 cm below the surface respectively. All sediments were found to be blue-grey clays or silts from top to bottom of the core. No evidence of terrestrial deposits lower than present sea level was encountered.

Further tests conducted on additional sedimentary landforms were undertaken during the course of fieldwork. These tests either uncovered archaeological sites, or were conducted during the archaeological prospection part of this research project and are reported on in “Chapter VIII – Archaeological Prospection Undertaken on Raised Marine Landforms on the Dundas Island Archipelago”.

Summary

The search for and discovery of coastal landforms revealed both erosional and accretionary features, and evidence of higher shorelines. Sedimentary landforms likely associated with higher sea levels were identified as occurring between the present shoreline and 17 m abl. Many of the features observed suggest a significant stillstand

occurred at 6 m abl resulting in the formation of multiple erosional features at this elevation. A basal peat date taken on western Baron Island reveals the peat has been growing at an elevation of 3.5 m abl since 3,880 BP. Tests undertaken in the mid and lower intertidal zone failed to reveal evidence of lower-than-present sea levels. While the evidence accumulated in these studies reveals higher sea levels, a precise chronology of sea levels was not derived from the tests and samples taken. Lake coring and analysis was the method chosen to provide a chronological dimension to the shoreline history of the Dundas Islands.

Lake Coring

Field research undertaken in 2001 focussed on recovering lake cores from three lakes on the southwestern side of Dundas Island. These three lakes were chosen because they were relatively accessible from the shoreline of Edith Harbour, and were different in (sill) elevations: BP Lake 6 m abl, SW Lake 13 m abl, and Top Lake 33 m abl. All cores were acquired using a Livingstone piston corer. The purpose of taking these cores was to assess the possibility that sea levels had been fairly stable, but slightly higher than today on the eastern side of Hecate Strait and Dixon Entrance. Due to the previously noted dating problems encountered while using a Livingstone corer in field research during 2001 (see “Chapter V – Dundas Island Archipelago Vegetation History as Reconstructed through Pollen Analysis”), a percussion coring methodology was adopted in the 2005 field season (Figure 37 and Figure 38). Percussion cores were recovered from six different lakes with sills between 16 m and 4 m abl (Table 10 and Figure 39). In all of these lake cores sedimentary transitions from mineral dominated deposition to organically dominated sediments were found. All lake elevations refer to the sill of the

lake. The following description of lake cores is organized by elevation from highest to lowest. Not all lake cores were analyzed and only those which were analyzed for diatoms are discussed in this section.

Figure 37. Percussion coring SLESS-Lake.



Figure 38. Percussion coring SB Bog.

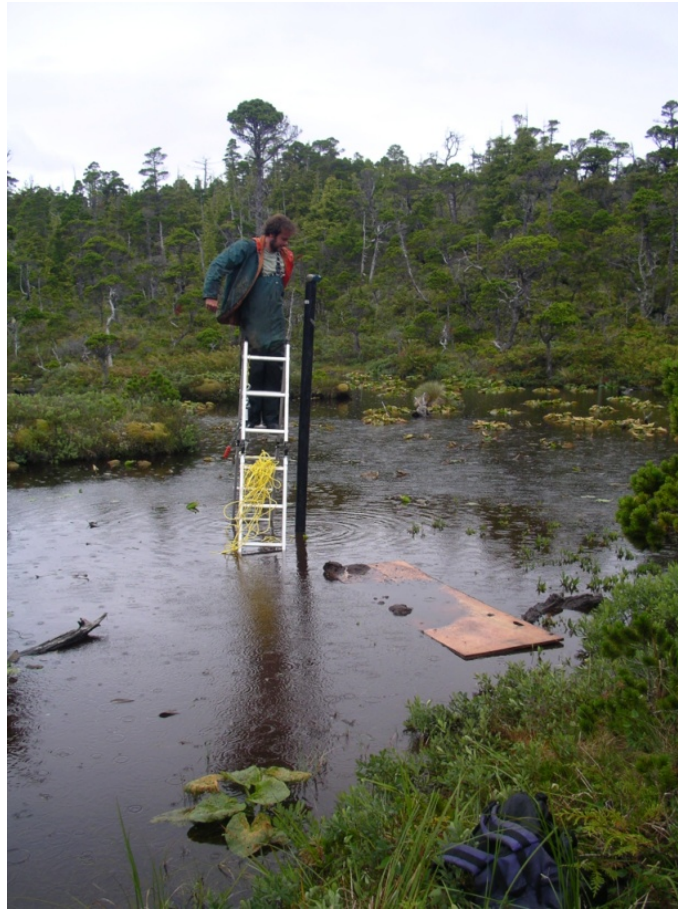
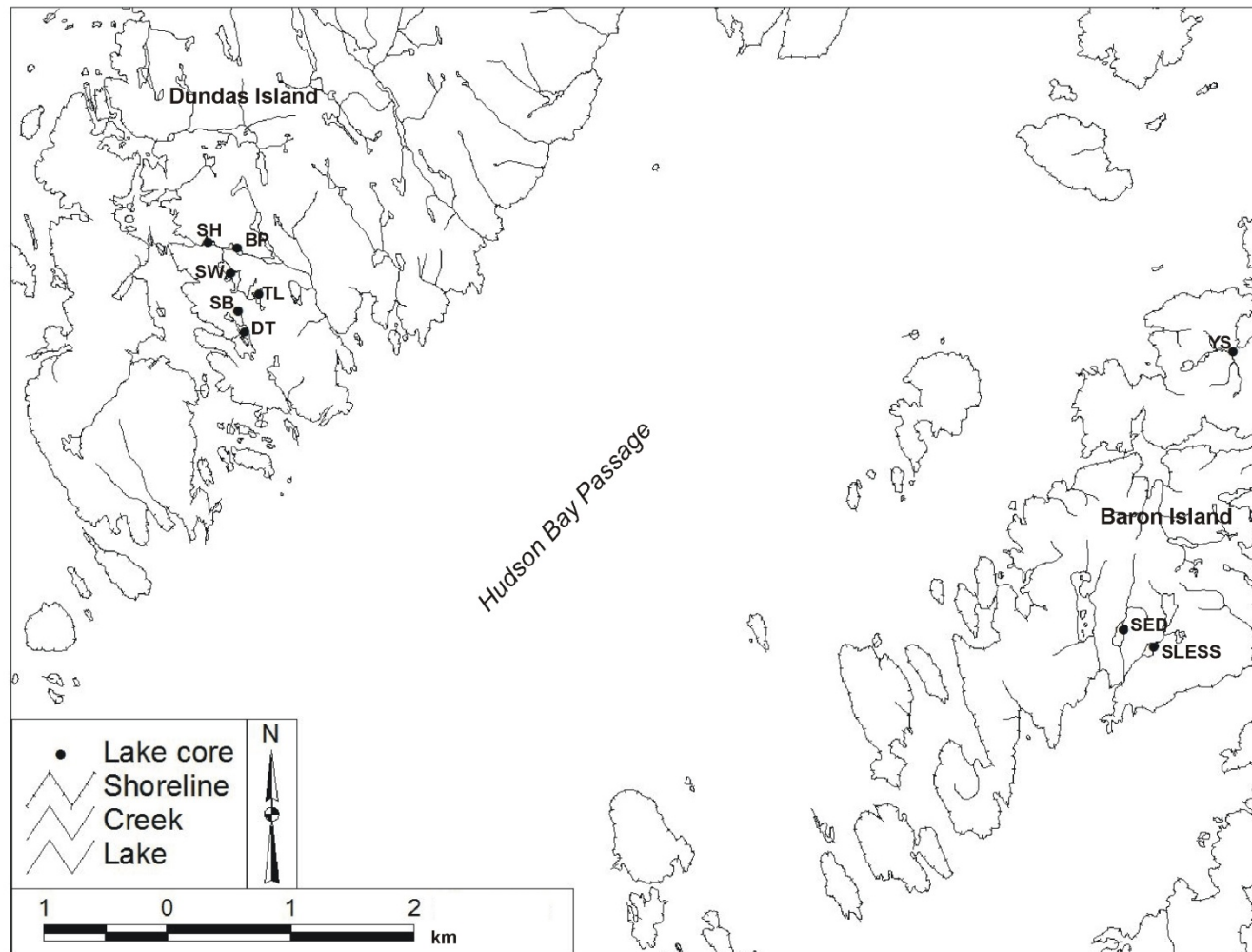


Table 10. Elevations of lakes cores on Dundas and Baron Islands.

Location	Year	Name	Elevation m abl
SW Dundas Island	2001	Top Lake	33
SW Baron Island	2005	SLESS Lake	16.25
SW Dundas Island	2001	SW Lake	13.5
SW Dundas Island	2005	SB bog	13
SW Baron Island	2005	SED Lake	10.25
SW Dundas Island	2005	DT Lake	7.25
SW Dundas Island	2001	BP Lake	6.5
SW Dundas Island	2005	SH Lake	6.25
NE Baron Island	2005	YS Lake	3

Figure 39. Locations of isolated lake basins cored on Dundas and Baron Islands.



Top Lake – 33 m abl

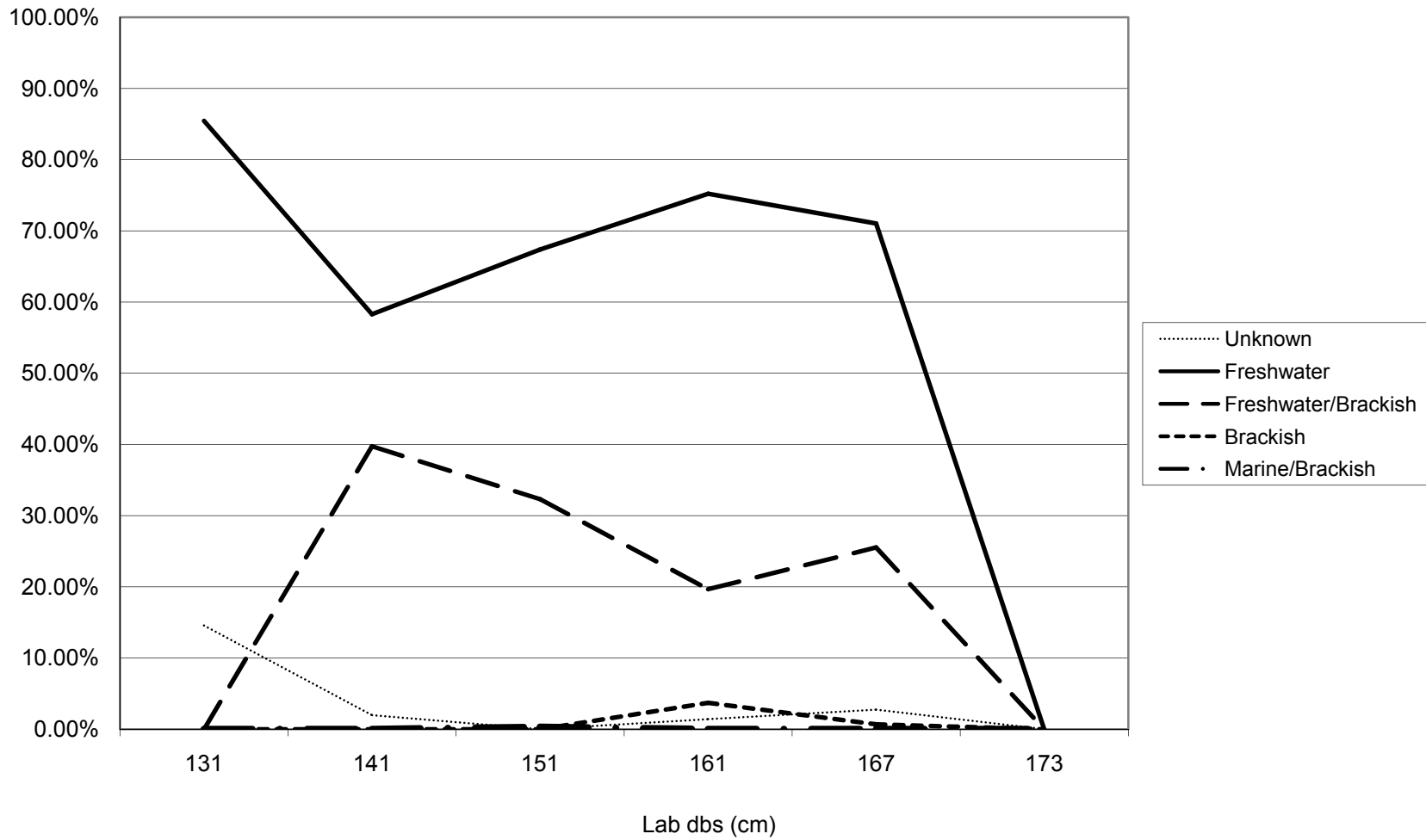
The third core taken from the Dundas Islands in 2001 was recovered from Top Lake, 33 m abl. This core is also discussed in “Chapter V – Dundas Island Archipelago Vegetation History as Reconstructed through Pollen”. The sequence has a clear transition from clay to gyttja between 570 and 560 cm dbs. An examination of diatoms from sediments on either side of the transition revealed only fresh water diatoms. Sample depths and dates recovered are as follows: 561 cm dbs at 12,385 \pm 30 BP (UCIAMS 31734), 555 cm dbs at 12,250 \pm 50 BP (UCIAMS 30933), and 543 cm dbs at 10,565 \pm 50 BP (UCIAMS 31733). This sequence reveals that the basin of Top Lake has remained fresh since some time before 12,385 BP.

SLESS Lake – 16.25 m abl

SLESS Lake is located at 16.25 m abl on SW Baron Island. A 185 cm core was extracted from the basal sediments of this lake. Due to compression the lab dbs of this core measures 175 cm. A transition from sandy silt to gyttja occurs in this core between 170 and 165 cm lab dbs. A radiocarbon date of 12,385 \pm 30 BP (UCIAMS 24509) was recovered from moss and seeds sampled at 170 cm lab dbs in the grey clay basal stratum.

Slides for diatom analysis were prepared from samples taken on either side of the transition between 173 and 131 cm lab dbs with sampling intervals of 10 cm except on either side of the transition where samples were taken at 6 cm intervals. Diatoms were found to be predominately fresh water species with *Cymbella ehrenbergii*, different species of *Fragilaria*, and *Pinnularia* dominating the assemblage (Figure 40 and Figure 41). Sediments at 173 cm lab dbs were found to be barren. Overall, there is no evidence that relative sea levels were higher than 16 m abl after 12,385 \pm 30 BP.

Figure 40. Salinity of depositional context based on diatom proxy indicators as percent of each sample counted from SLESS Lake.

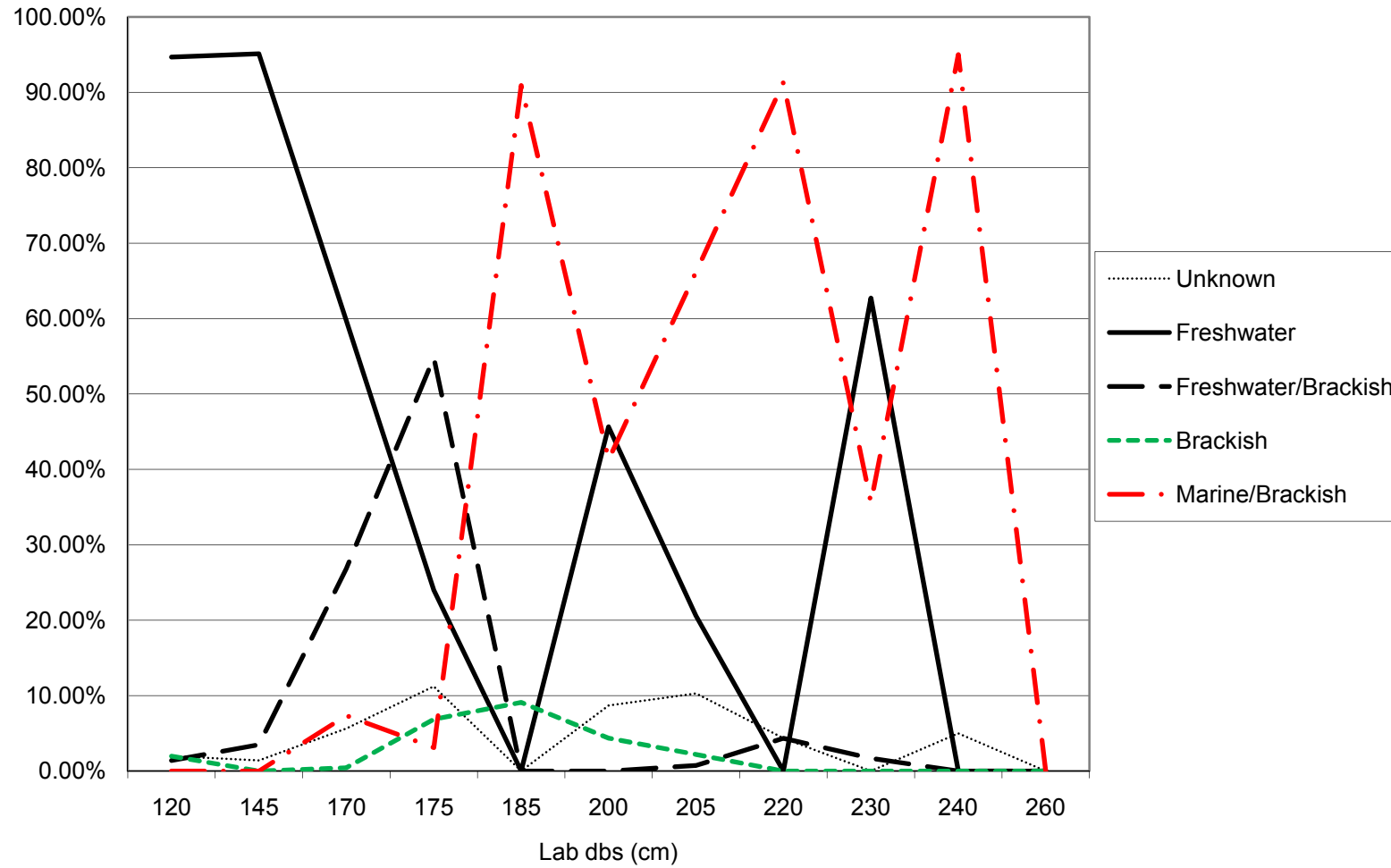


SB Bog – 13 m abl

SB bog includes a very shallow lake located on the SW side of Baron Island. The sill of this lake was recorded in the field at 13 m abl. A sediment core measuring 343 cm long was recovered from the sediments of this shallow lake, although some clay fell out of the bottom of the core when it was extracted. The remaining sediments in the core measured 282 cm. A transition from clay-dominated sediments to gyttja was found between 177 and 165 cm lab dbs. The transitional sediments are brownish-grey clay. A radiocarbon sample combining moss and seed macrofossils was selected from 174 cm lab dbs. This sample dated to 12,170 \pm 160 BP (UCIAMS 24508).

Diatom slides were prepared from samples taken on either side of the transition between 260 and 120 cm lab dbs. There is a change in diatom types associated with the sedimentary transition (Figure 42). Below the transition the dominant species of diatom are marine, in particular *Thalassiosira*, *Rhabdonema*, and *Cocconeis* taxa. Above 175 cm dbs fresh water diatoms are dominant, in particular *Aulacoseia lirata*, *Eunotia*, and *Pinnularia* species (Figure 43). Samples below 175 cm lab dbs tended to have low frequencies of diatoms and counts for each slide were lower than 300, and, some slides were found to be barren. In some cases, fragments of marine diatoms were counted, possibly inflating the marine signature in Figure 42. Regardless, the appearance of marine diatoms below 175 cm lab dbs reveals at least brackish conditions 13 m abl at and before 12,170 BP.

Figure 42. Salinity of depositional context based on percentage of diatom proxy indicators per samples counted from SB Bog (not including barren samples).



SW Lake – 13 m abl

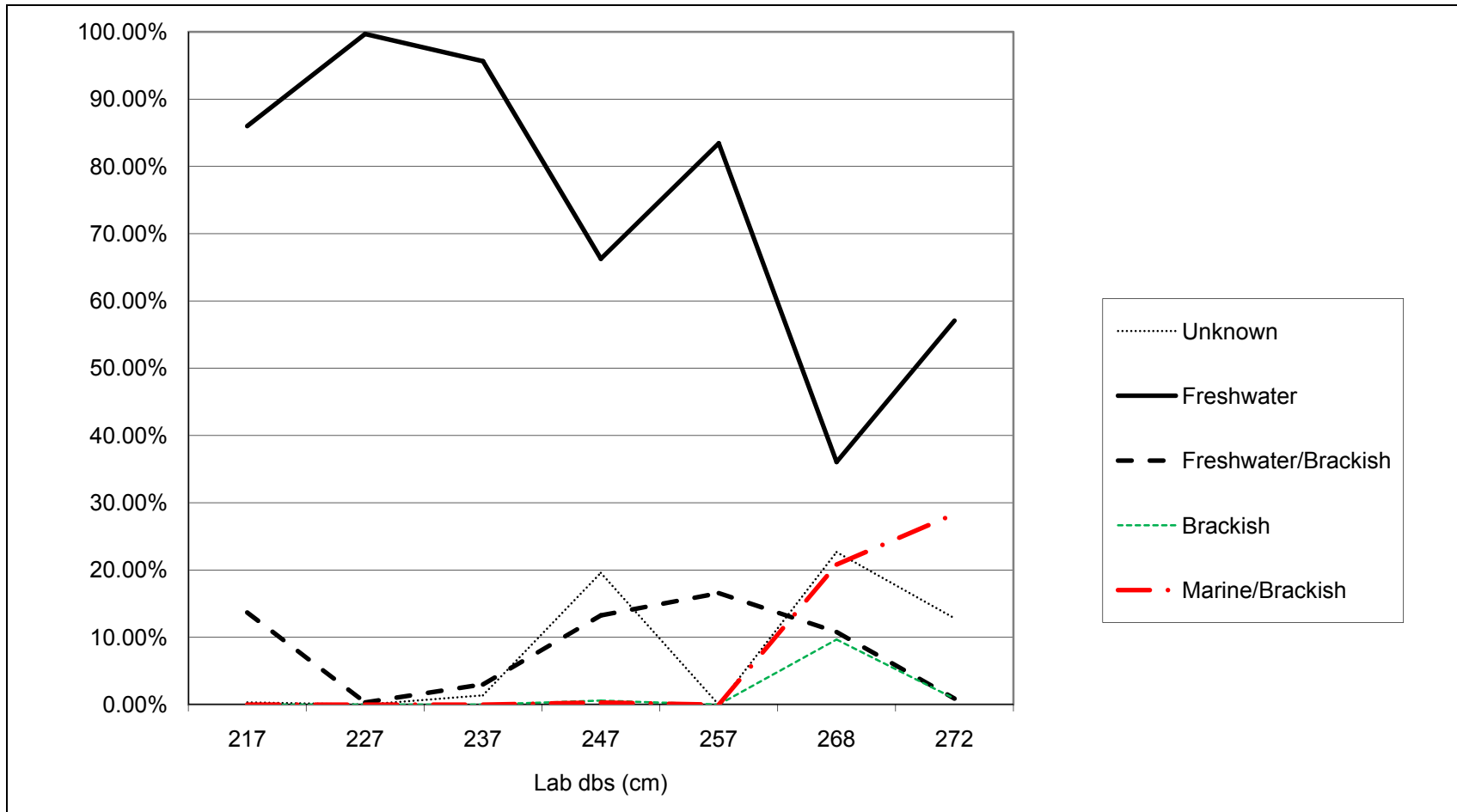
SW Lake is situated 13 m abl and is part of the same drainage system as BP Lake. A 233 cm long core was recovered from SW Lake. An examination of diatoms from SW Lake revealed a change in assemblages associated with a lithological transition from clay to gyttja 222 cm dbs. A date of 12,135 \pm 40 BP (CAMS 82220) was recovered from 220 cm dbs. These results indicated a transition from brackish to fresh water conditions 12,135 BP at 13 m abl. Formal counts of diatoms below 220 cm were not undertaken as numbers were found to be very low. However, diatoms found include marine species *Rhobdonema minutum* and *Paralia sulcata* from 228 cm dbs. At 222 cm dbs, diatom species were found to be fresh water and the gyttja from this point to the surface of the core suggests that there was a lack of subsequent marine incursion into this basin.

SED Lake – 10.25 m abl

SED Lake is located 10.25 m asl on southwestern Baron Island. An 820 cm core was taken from this lake, but some fell out of the bottom of the tube when the core was extracted. The compressed sediments remaining in the core tube measured 415 cm with a transition between clay and gyttja between 266 and 257 cm lab dbs. Clay sediments below 275 cm dbs appeared to have been stretched downwards, likely when lower sediments fell out of the bottom of the sampling tube. Sediment below 266 cm lab dbs consists of grey clay with occasional pebbles. Above 257 cm lab dbs, sediments are brown organic gyttja. The interval between 266 and 257 cm lab dbs is characterized by brown clayey sand. A pine needle fragment was selected for radiocarbon dating at 270 cm dbs. This sample was dated at 10,320 \pm 40 BP (UCIAMS 24510).

Diatom slides were prepared from sediment samples taken from either side of this transition, between 272 and 217 cm lab dbs. Samples below 275 cm dbs were not prepared as the sediments in the core appeared to be stretched on recovery. Between 268 and 257 cm lab dbs there is a marked increase in the number of marine diatoms that were counted, in particular *Thalassiosira* and *Cocconeis* species (Figure 44). Throughout, the fresh water *Aulacoseira lirata* diatom signature remains strong (Figure 45). This evidence suggests that a high tide lagoon with significant fresh water input existed at this elevation at 10,320 BP and for some time slightly before this. After this time sea level fell, accounting for the change from brown sandy clay to gyttja.

Figure 44. Salinity of water derived from diatom proxy indicators and depth of samples counted from SED Lake.



BP Lake – 6.5 m abl

From the core at BP Lake, 6.5 m asl, a total of 509 cm of sediments were recovered. Whole and fragmentary marine shells were clearly visible in the sediments at 295 cm dbs. An analysis of diatoms from sediments between 215 and 210 cm dbs revealed a transition from brackish (below) to fresh (above) water conditions. Three in situ shell fragments were identified: a clam shell fragment at 295 cm dbs, a *Tresus nuttallii* (horse clam) shell at 425 cm dbs, and a clam shell fragment at 465 cm dbs. Many other small shell fragments were visible in the sediments of this core. An examination of diatoms from 505 cm dbs revealed marine diatoms. From the brackish to fresh transition a date of 8000 \pm 300 (CAMS 82216) was returned and from 505 cm dbs a date of 9735 \pm 40 (CAMS 82217) was returned. The date of 8,000 BP may be suspect due to its large standard deviation. There is a clear transition from marine to fresh water diatoms coincident with the sedimentary transition between 215 and 210 cm dbs (Table 11).

Table 11. Transition in salinity as indicated by diatom counts undertaken on BP Lake core samples.

CORE	DEPTH	UNKNOWN	FRESH-WATER	FRESH-WATER/ BRACKISH	BRACKISH	MARINE/ BRACKISH	TOTAL
BP	210	2.36%	93.27%	4.04%	0.00%	0.34%	100%
BP	215	16.24%	7.96%	17.52%	2.23%	56.05%	100%

SH Lake – 6.25

SH Lake is located on southwestern Dundas Island in the same drainage system as BP Lake, SW Lake, and Top Lake. The lake sill is situated 6.25 m abl. A core measuring 150 cm was retrieved from this lake. This core was compressed to 125 cm lab

lbs. A transition in the core from a grey sandy silt to gyttja occurs at 72 cm lbs. Some of the sediments below this point are stained brown and black and have a gyttja-like appearance but are more mineral rich as indicated by coarse sand grains. A combined sample of insect and plant macrofossils from 73 cm lab lbs was selected and radiocarbon dated to 5280 \pm 100 (UCIAMS 23807).

Diatom slides were prepared on samples from either side of this sedimentary transition from 123 to 44 cm lab lbs. A shift from marine diatoms to fresh water species occurs between 69 and 64 cm lab lbs (Figure 46 and Figure 47). The results of the analysis of this core from SH Lake reveals that sea levels were at least 6.25 m abl at and before 5,280 BP.

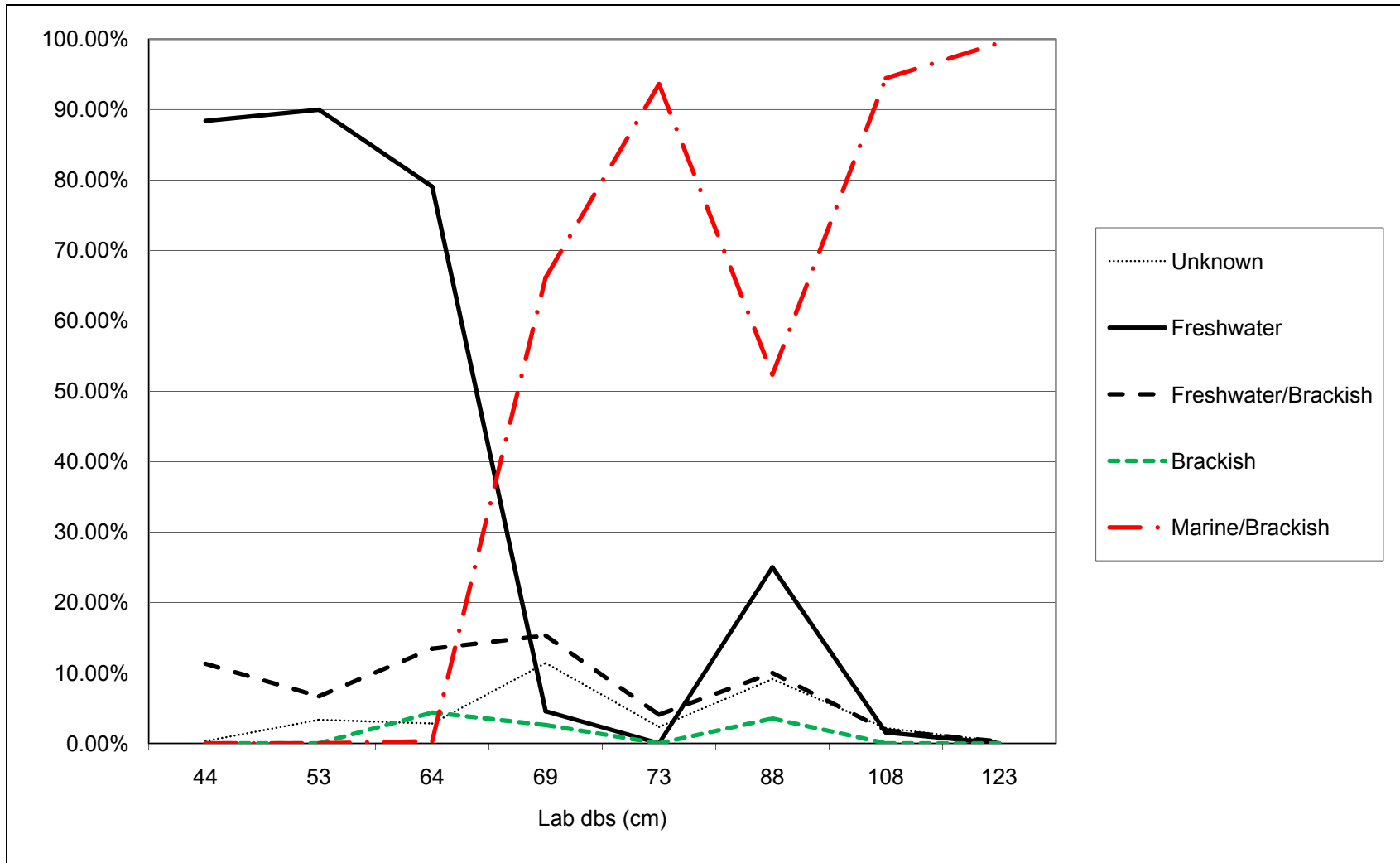
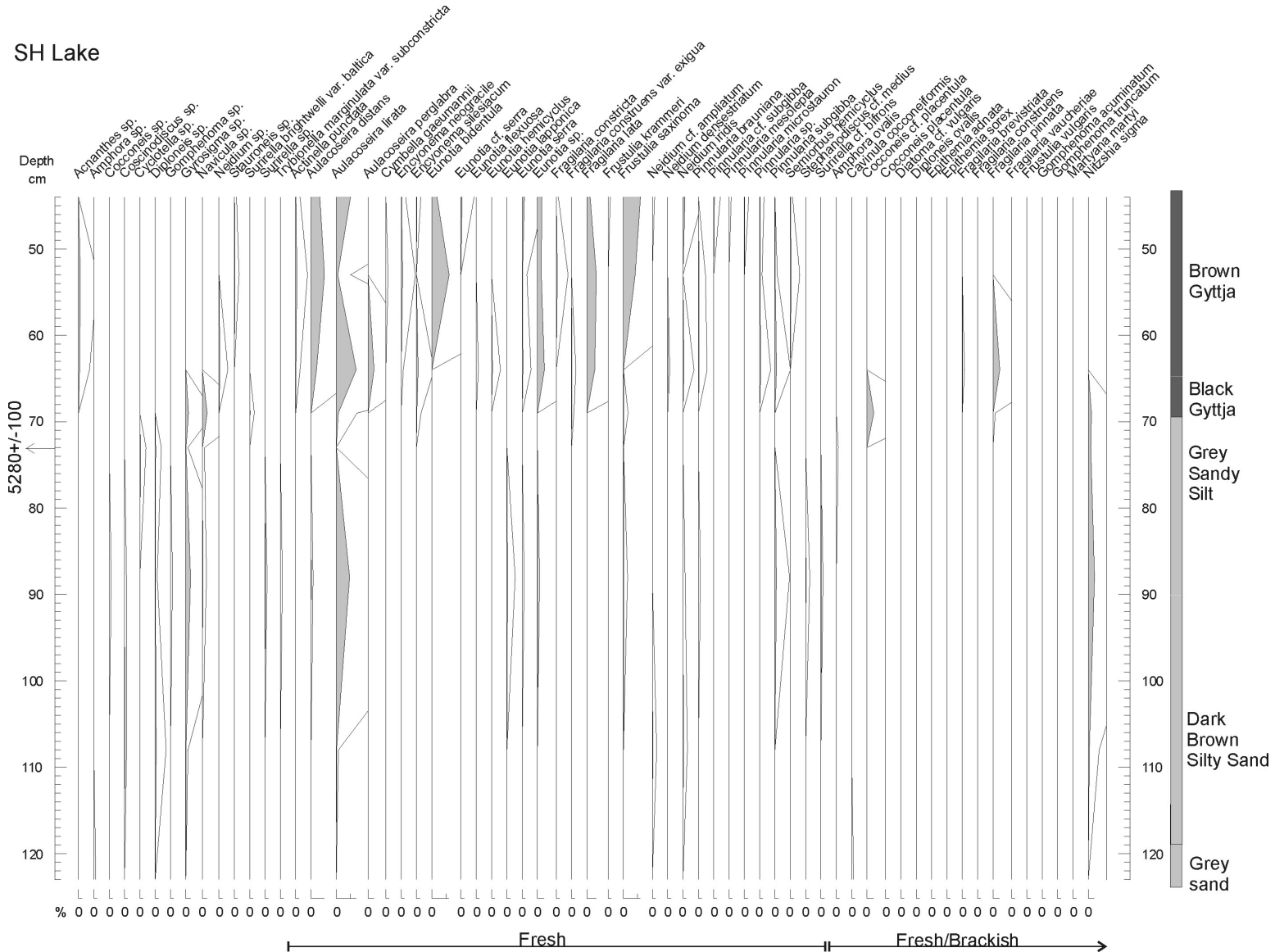
Figure 46. Salinity of water derived from diatom proxy indicators and depth of samples counted from SH Lake.

Figure 47 Percentage diagram of diatoms counted (and 10X exaggeration) from SH Lake, figure continued on next page.



Discussion

The results of lake coring and diatom analysis reveal a unidirectional trend in sea level regression since late Pleistocene times (Figure 48). This analysis has provided data enabling the construction of a sea level curve for the Dundas Islands (Figure 49). The sea level curve has been created by plotting the elevation of marine to fresh water transitions on the Y-axis and the results of radiocarbon analysis on the X-axis. The results reveal marine influence 13 m abl at 12,170 \pm 160 and 12,135 \pm 40 BP from two different sampling locations: SB Bog and SW Lake. Near-contemporaneous sediments from SLESS Lake at 16 m abl (12,385 \pm 30 BP) were found to contain fresh water diatoms. The sea level curve indicates a slow regression after this time. Shortly after 10,320 \pm 40 BP sea levels had fallen to 10 m abl as indicated by diatom analysis of sediments from SED Lake. Sometime after 8,000 \pm 300 BP (BP Lake) and before 5,280 \pm 100 BP (SH Lake) sea levels stabilized at around 6 m abl. This stillstand is also supported by the multiple occurrences of geomorphic and sedimentary features found at about 6 m abl. By 3,885 \pm 20 BP peat began to form on grayish-blue clay on western Baron Island 3.5 m abl indicating the establishment of vegetation in an area formerly in the intertidal zone and unvegetated. Between 3,885 BP and present, sea levels fell from 3.5 m abl to their present level. Sub-tidal investigations, although limited in scope, have failed to reveal terrestrial deposits below the present day tide line, suggesting that sea levels did not regress below their present day levels.

Figure 48. Schematic illustration of the relationship of lake and basal peat core transitions and elevations.

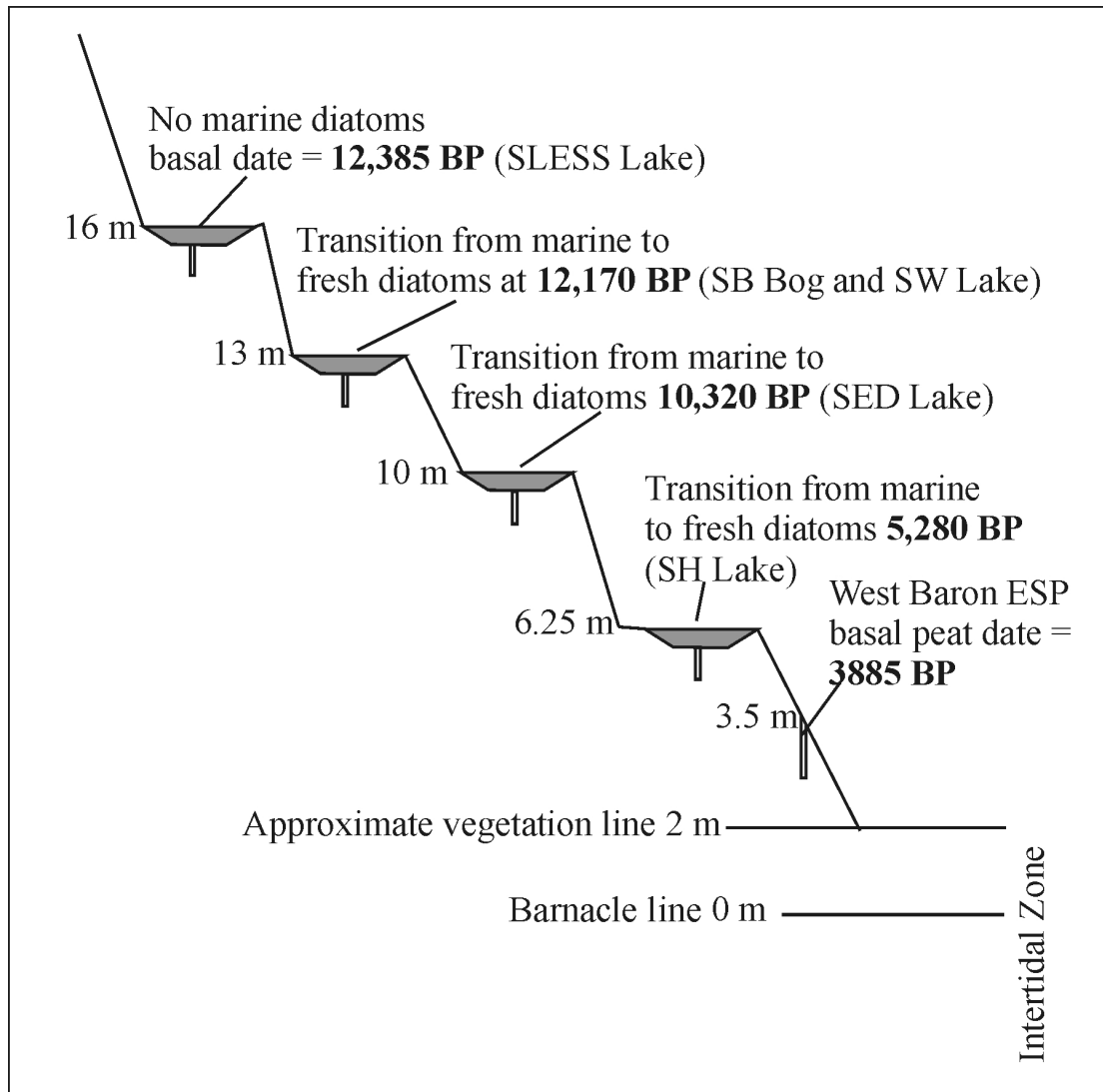
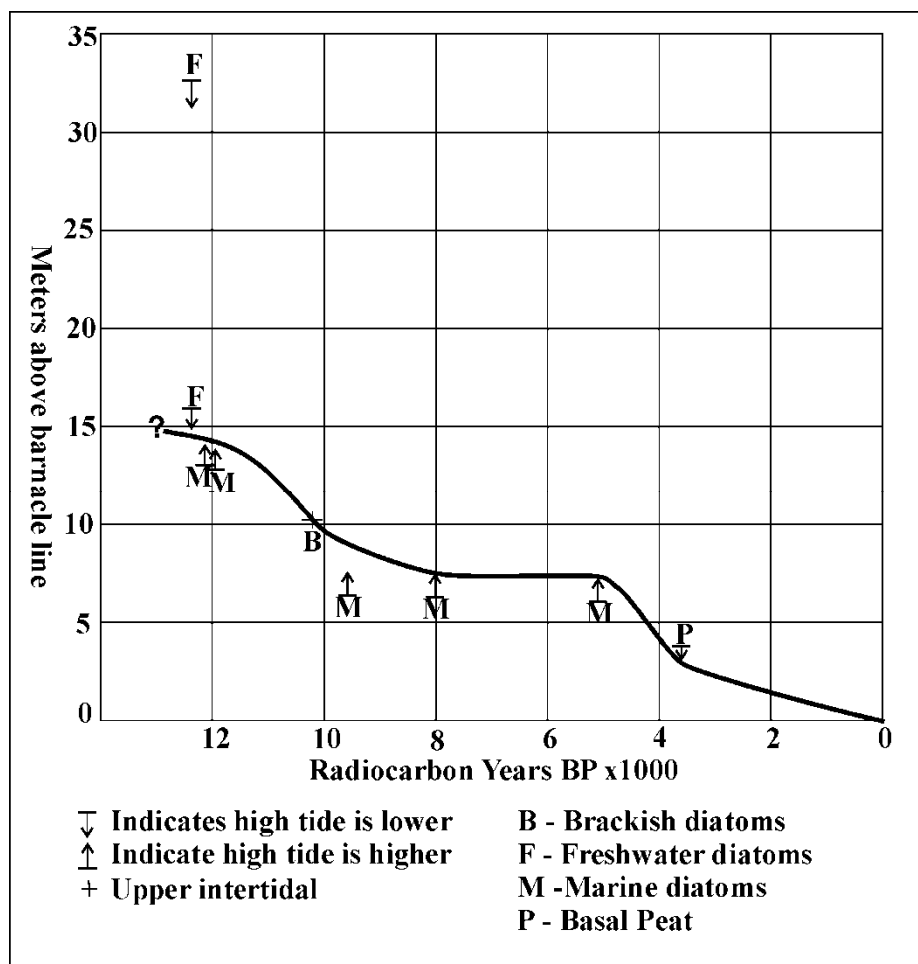


Figure 49. Sea Level Curve for the Dundas Islands based on palaeo-environmental proxy indicators.



As with any sea level curve, there are limitations with the curve created for the Dundas Islands. In particular, this curve is very smooth with little oscillation. This may be a result of the time gaps between samples taken. Furthermore, most of the cores have only one date close to the sedimentary transition from marine to fresh water conditions. In most cases, these dated samples are from either before or after the transition and the amount of lag time cannot be assessed.

As expected, the sea level curve generated for the Dundas Islands differs from curves generated for other parts of the northern Northwest Coast. In general, immediately following deglaciation, outer coastal areas had sea levels that were

significantly lower than today. It is hypothesized that sea levels reached their maximum lowering to the west of the Dundas Islands sometime after 13,000 BP and remained low until 12,400 BP (Josenhans et al. 1997; Barrie and Conway 1999). Indeed, evidence from western Hecate Strait demonstrates that prior to 12,200 BP relative sea level was at least 150 m lower than today as a result of the forebulging of the continental margin (Josenhans et al. 1997; Fedje and Josenhans 2000). Following 12,000 BP there appears to have been a collapse of the forebulge (Fedje et al. 2005b) and sea levels began to rise until 8,800 years BP where they stabilized at 15 m above present-day sea level, forming the early Holocene raised marine features along the eastern shore of Haida Gwaii.

In contrast to outer coastal areas, regions closer to the mainland and located within the isostatic depression of the Cordilleran Ice Sheet had sea levels that were relatively higher than they are today. For example, at Port Simpson shorelines on the mainland coast were 50 m above present-day sea level at 12,600 BP (Archer 1998; Fedje et al. 2005b). The earliest dates of marine conditions in the Prince Rupert area, 12,700 BP, indicate that sea levels were higher than 11 m (Clague 1984). In southeast Alaska, evidence of raised sea levels is found in many parts of the Alexander Archipelago. On the eastern side of the archipelago, sea levels appear to have been in the vicinity of 80-60 m above present sea levels ~12,500 BP (Mann 1986). Coastal areas that extend inland, such as fjords and river valleys, were isostatically depressed even more and sea levels were as high as 200 m above present-day sea level following deglaciations in place like Kitimat at 10,500 BP (Clague 1984) and farther south in the Fraser Valley at 12,250 BP (James et al. 2002). After this time of maximum transgression, the relative sea level in

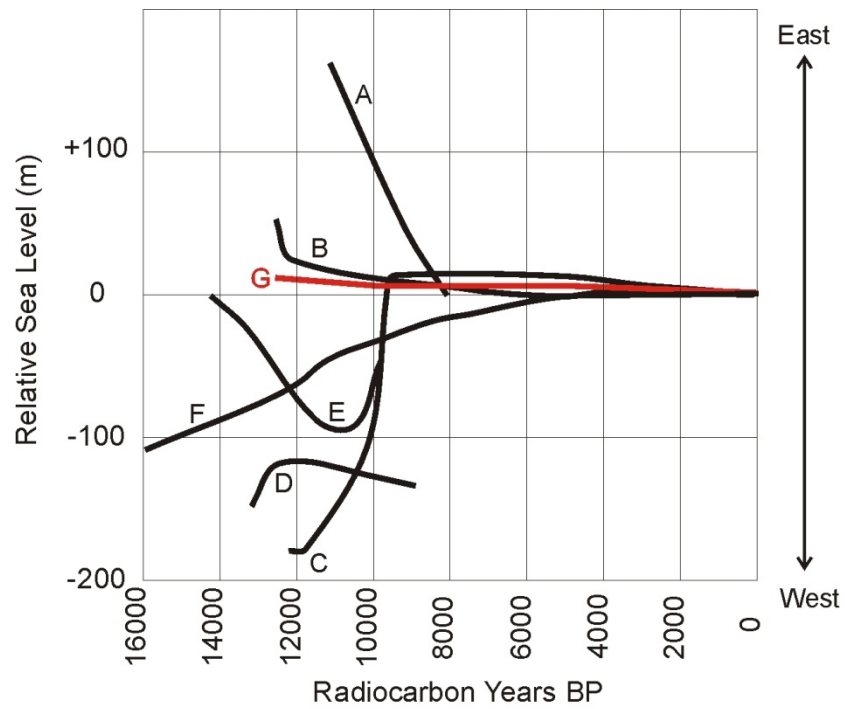
these areas plunged to modern day sea levels by 9000-8000 BP (Clague 1984; James et al. 2002) in association with isostatic rebound.

In comparison to all of these areas, the Dundas Island sea level curve suggests a relatively slow sea level fall from 13 m abl to 0 m abl over the past 12,000 years. This regression has stranded relict shorelines inland and away from present shorelines. However, the small change in elevation of the shoreline may have provided more relative stability, and hence greater possibility for archaeological accumulation, than areas where sea level change has been rapid. These data appear to support the assertion that the Dundas Island Archipelago lies in proximity to this hypothesized sea level hinge of the northern coast of British Columbia (Figure 50). The relative stability of local sea levels is the result of crustal displacement, through isostatic rebound, keeping pace with global eustatic sea level rise (Figure 51).

Conclusion

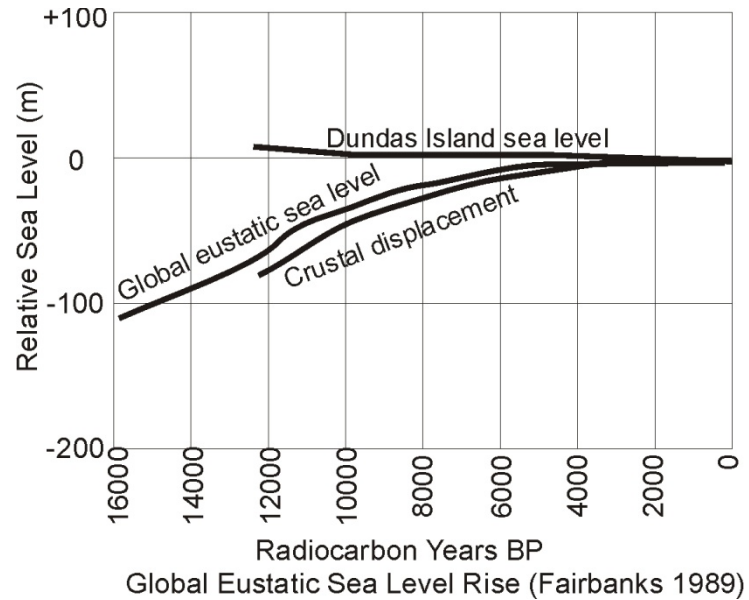
This chapter presents the results of palaeo-environmental research oriented at investigation and discovery of past sea levels and relict shorelines on the Dundas Islands. Shorelines were found to have been 13 m abl ~12,000 BP and, from then on, to slowly fall to present day levels. An early Holocene stillstand is suggested by both geomorphic and lake core data. Before 12,350 BP the sea level history of the study area remains unknown. Erosional features found to 24 m abl and sedimentary features found to 17 m abl suggest that sea levels may have been higher than 13 m prior to 12,350 BP.

Figure 50. A Comparison of Local Sea Level Curves.



- A - Kitimat (Clague 1984; Fedje et al. 2005a)
- B - Prince Rupert/Port Simpson (Archer 1998; Clague 1984; Eldridge and Parker 2007; Fedje et al. 2005a)
- C - Southern Haida Gwaii (Fedje et al. 2005a)
- D - Central Hecate Strait (Hetherington 2002)
- E - Northern Hecate Strait (Hetherington 2002)
- F - Global eustatic sea level rise (Fairbanks 1989)
- G - Dundas Islands Archipelago**

Figure 51. Chart comparing global eustatic sea level rise and localized crustal displacement on the Dundas Islands. Crustal displacement calculated by subtracting Dundas Island sea level from global eustatic sea level.



The sea level curve for the Dundas Islands differs from sea level curves from other areas of the northern Northwest Coast as a result of the differing effects of isostatic depression relative to where ice loading on the continental crust occurred and global eustatic sea level rise. Significantly, the collection and analysis of sea level data provides a palaeo-environmental basis from which to conduct a localized survey to find archaeological sites associated with relict shorelines.

Chapter VII – Modeling Relict Shorelines and Predicting Archaeological Site Locations

Introduction

The creation of a sea level curve and reconstruction of the vegetation history for the Dundas Island Archipelago were two steps towards the goal of finding and dating archaeological sites older than 5,000 BP in Coast Tsimshian Territory. As they are linear landscape features, past shorelines can be predicted with some accuracy based on the results of the relative sea level curve produced for the area. However, this data set is not enough to enable a successful archaeological inventory of raised shorelines as shoreline locations are not indicated horizontally. For this reason, additional geographic information was acquired prior to undertaking archaeological prospection in the field. This chapter describes the methods and results used to choose areas where relict shorelines and archaeological sites would most likely be found.

This chapter first reviews the methods used to model the locations of shorelines in the study area. The second part of this chapter describes additional geographic and cultural data sources that were considered in choosing regions to conduct archaeological surveys. The results of these tasks culminated in the production of high resolution contour maps for different parts of the study area that were then used to guide archaeological prospection.

Palaeo-Shoreline Modelling

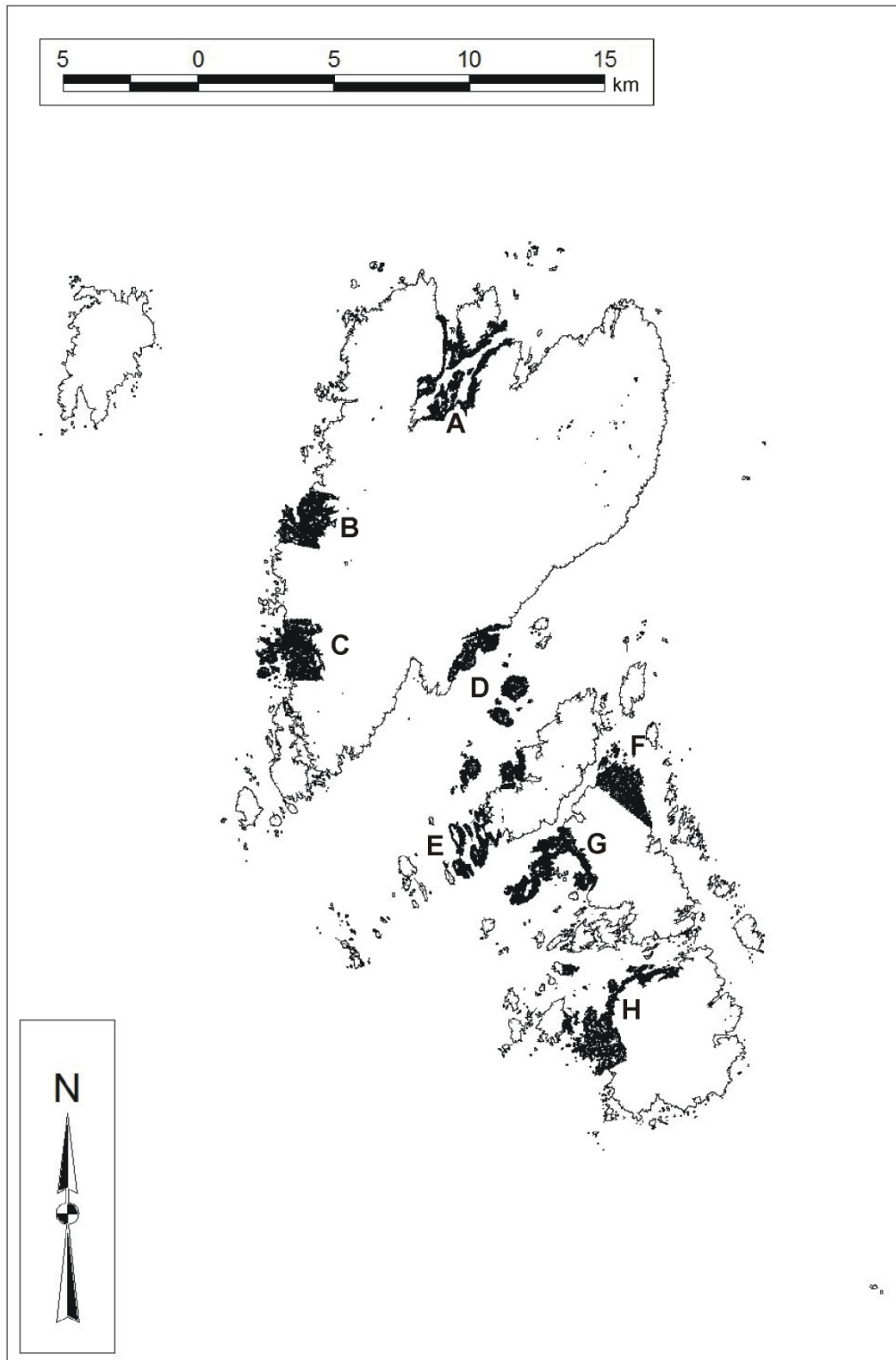
While the sea level curve generated for the Dundas Islands provides information on the elevation of relict shorelines during specific periods in the past, finding the

location of these shorelines on the landscape is not as easy a task as it might at first seem. Indeed, the sea level curve suggests that the shoreline of the region has fluctuated 13 m over the last 12,000 years. However, the largest scale maps for the region are Terrain Resource Information Management (TRIM) 1:20,000 scale maps with 20 m contours. To locate a specific elevation, for example 6 m a.s.l., from one of these 1:20,000 maps is not possible. Furthermore, as with most regions of the Northwest Coast, the coastal fringe of the Dundas Islands is heavily forested by coniferous trees, making archaeological sites and geomorphic feature detection from aerial photographs difficult. In general, the forest canopy obliterates the details of the landscape needed to positively identify these features from aerial photographs and reconnaissance, or other remote sensing techniques. As a result, remote sensing techniques have rarely been employed for archaeological purposes on the Northwest Coast. However, recent innovations in remote sensing have created the potential for generating highly accurate digital elevation models beneath forest canopies. These technologies include digital photogrammetry, Interferometric Synthetic Aperture Radar (IFSAR), and Light Detection and Ranging (LIDAR), which all have the potential of producing bare earth digital elevation models (DEMs) from remotely sensed data in forested areas.

Digital Elevation Model Generation

DEM data were produced photogrammetrically by Integrated Mapping Technologies, Inc. (IMT) using existing 1:20,000 aerial photographs. The resulting DEM is estimated by IMT to have an error of +/- 1 m. From these data, eight different shoreline areas of the Dundas Islands were mapped with 2 m contour intervals (Figure 52). Several different criteria were considered in the selection of areas for high resolution

Figure 52. Areas chosen for microtopographic digital elevation model generation derived from digital photogrammetric techniques.



mapping. These criteria are considered in the following section. Some of these base maps have already been presented in “Chapter VI - Dundas Island Archipelago Late Pleistocene and Holocene Sea Level History”, and large scale maps of each area are presented in “Chapter VIII – Archaeological Prospection Undertaken on Raised Marine Landforms on the Dundas Island Archipelago”. The areas for which 2 m contour maps were generated are as follows (letters refer to areas mapped on Figure 46):

- A. Brundige Inlet, northern Dundas Island
- B. Western Dundas Island #1
- C. Western Dundas Island #2
- D. Hudson Bay Passage and the Nares Islets
- E. West Baron Island
- F. Northeastern Dunira Island
- G. Western Dunira Island
- H. Northwest Melville Island

Archaeological Site Potential

Archaeological potential modeling has commonly been undertaken in British Columbia for the purpose of cultural resource management. Potential models are often formalized cartographically with areas of high, medium, and low archaeological site potential. Often, these types of maps guide decisions regarding archaeological management strategies and priorities. Areas mapped as being high in archaeological site potential will be more likely to have archaeological impact assessment work undertaken if threatened by land-altering development. The same basic premise has been used to guide archaeological surveys based on specific research oriented questions.

Two regional studies in particular have focussed on choosing areas with high archaeological site potential, based on geographic criteria, in order to search for archaeological sites dating to the late Pleistocene or early Holocene time periods. Punke (2001) undertook a formalized and GIS-based study of archaeological potential in western Oregon to guide archaeological surveys for late Pleistocene sites. As the coast of Oregon during this time was below current sea level, this potential model focussed on inland areas that would have been targeted by coastal populations. Field-testing of the model failed to find any archaeological sites although crews revisited and dated the Indian Sands site, which was recorded prior to the potential modeling study (Davis et al. 2004; Moss and Erlandson 1998).

On Haida Gwaii, an archaeological inventory of relict raised shorelines was undertaken by Fedje and Christensen (1999) and Fedje et al. (2005a). These investigators used several criteria to choose areas, but did not generate a GIS-based archaeological potential model. In addition to acquiring a photogrammetrically derived DEM to map the 15 m stillstand landforms in southern Haida Gwaii, areas were chosen

based in part on protection from the open sea and the location of other early Holocene archaeological sites in Haida Gwaii. These sites included known early Holocene intertidal lithic sites and the raised beach aspect of the Arrow Creek site. Intertidal lithics are lag remnants of early Holocene archaeological sites now exposed in the intertidal zone. The 1-metre contour interval mapped topography around Arrow Creek served as a key example of how early sites could appear on these maps (Fedje et al. 1996). Most prominent was the wide, flat terrace bordering the 15-metre highstand mark of what is now Arrow Creek, but which then would have been a saltwater arm of Matheson Inlet.

Also evident was a gently sloping (paleo)intertidal zone [Fedje et al. 2005a: 171-172].

This archaeological potential scheme, although not formalized in a GIS-based system was very successful; the resulting archaeological testing discovered a total of 16 raised beach sites.

An archaeological inventory project in Naden Harbour, at the northern end of Haida Gwaii, adopted a methodology similar to that undertaken in the southern part of the Islands (Stafford and Christensen 2000); however, high-resolution contour maps were not produced. Marine terraces are highly visible on the ground and survey crews reported 20 shell midden complexes on raised beaches. In several instances, more recent shell middens were located directly below shell midden deposits on higher terraces. This suggests that people settled in the same locations for millennia and moved their settlement down slopes as sea levels dropped through the Holocene.

Based on the results of these research projects, a number of different criteria were considered in choosing geographic regions in the Dundas Islands with potential for archaeological sites dating to the late Pleistocene and early Holocene. These criteria are discussed below. The use of these criteria was, in part, based on the results of shoreline settlement patterns described for Moresby Island (Mackie and Sumpter 2005).

Aspect

Aspect refers to the cardinal direction to which a specific location is exposed. While maximum sunshine is gained through southern exposure, a southerly facing settlement can be less desirable as storms in this area often blow from the southeast. Significantly, in their analyses of archaeological site locations in Gwaii Haanas, Mackie

and Sumpter (2005) found that a higher number of early Holocene sites than expected faced in a northerly direction, in particular northeastwards, possibly as this direction is protected from southeasterly storm winds. The areas on the Dundas Islands chosen for mapping included samples of shoreline facing in all cardinal directions but overall there is a slight bias in favour of northwest and northeast facing landforms. Many of the areas chosen have highly sinuous shorelines with islets, skerries, isthmuses, and inlets and are oriented in multiple cardinal directions as a result.

Exposure

Exposure refers to the amount of wind and wave-fetch that shorelines face. Areas with low exposure tend to have less wind and wave fetch and tend to be low energy environments. In the study area, high exposure shorelines tend to be less intricate and more linear, and generally have fewer islands. Areas of low exposure tend to be flatter and more intricate in terms of the amount of shoreline with small islands, inlets, or bays.

Physical shore zone map data were acquired from Coastal and Ocean Resources, Inc., and considered in the selection of areas for survey. These data estimated the amount of exposure in a given area based on the mapped intertidal and subtidal species (Howes et al. 1995). Shorelines were mapped as exposed, semi-exposed, semi-protected, and protected. Very little of the shoreline on the Dundas Islands is mapped as 'exposed' although the western side of the Islands have a massive wave fetch through Dixon Entrance from the Pacific Ocean. Most of the shoreline on the more exposed sides of the islands is mapped as being semi-exposed. Areas on the western side of the Dundas Islands (B and C on Figure 52) and western side of Baron Island (E on Figure 52) were selected based on their proximity to semi-exposed areas, but which included protected

pocket beaches. Other map areas (Figure 52) are dominated by semi-protected and protected shorelines based on faunal indicators.

Slope

People will tend to inhabit flat areas or will flatten areas in order to inhabit them. For this reason, archaeological sites were found situated on flat alluvial terraces 15 m above the present shoreline in Gwaii Haanas (Fedje et al. 2005a). However, in some regions these flats were found to be saturated and too boggy for human habitation. Compared to Gwaii Haanas, the overall topography of the Dundas Islands is flatter and lower. Another problem with flat areas is associated with the intertidal zone and the 7 m tidal fluctuations. This can render low tide shorelines very distant from the high tide line. This may have affected whether a location was chosen for habitation in the past or not. Practically, surveys in these areas are made difficult by the large intertidal flats as well as the distances needed to walk in order to gain elevation. Areas of moderate slope in more protected areas were chosen preferentially, enabling ease of access and boat anchoring, as well as providing less peat bog rich vegetation cover (in particular areas A, D, E, G, and the northern part of H, Figure 52).

Distance to fresh water

The distance to fresh water can be an important aspect in settlement location. This criterion can be difficult to derive from map-based data, as streams are so common on the Northwest Coast that many remain unmapped on basic TRIM sheet data. In their analysis of settlement patterns on Moresby Island, Mackie and Sumpter (2005) found a lack of correlation between mapped stream locations and archaeological site locations. They suggest that this pattern may be the result of the lack of adequate mapping of creek

features. Despite this limitation, this criterion was used in the selection of areas A, B, C, F, and H (Figure 52) as they all have major creeks as mapped on TRIM sheet data.

Cave or rock shelter potential

Caves and rock shelters are often targeted places of human use (Butzer 1982). Rock shelters tend to be found in steeper topography. Solution caves are common in limestone. Areas on the north side of Dundas Island and west side of Dunira Island are mapped as having massive limestone (Hutchison 1982) and this area was selected for high resolution DEM generation (A and F on Figure 52). In addition, the steep topography on the west side of Baron Island (E on Figure 52) was considered as high in potential for rock shelters.

Proximity to salmon streams

Salmon is a key and predictable resource for many populations that thrived on the Northwest Coast. Mackie and Sumpter (2005) found that a larger percentage of early Holocene archaeological site locations were closer to salmon streams than expected. We included some known salmon streams in the areas chosen for high resolution mapping. Brundige Creek and Sandy Bay Creek which empty into Brundige Inlet have salmon bearing streams included in the FISHwizard database (Freshwater Fisheries Society of British Columbia 2005). Other salmon streams noted on the islands have not been identified in this database. Part of the mapped area on the northwestern side of Melville Island (H on Figure 52) was chosen due to its proximity to a salmon stream observed in the field.

Proximity to later archaeological site locations

Mackie and Sumpter (2005) found that only 4% of sites located on South Moresby Island share an early Holocene and late Holocene component. They call this criterion site co-occurrence. In other areas, such as Naden Harbour (Stafford and Christensen 2000) site co-occurrence also occurs frequently. Some of the areas selected for high resolution DEM generation were chosen on the basis of there being a significant late Holocene site in the area and enough topography that there may be co-occurring sites on higher terraces as well. Large later Holocene village sites located in the Nares Islets and northeastern Dunira Island (D, E, and F on Figure 52) were a criterion in the choice of these areas. All other mapped areas (Figure 52) have cabins and smaller midden sites.

Physical shore zone type

The physical shore zone maps produced were used to ensure that areas chosen for high-resolution DEM generation had significant sedimentary accumulations in the current intertidal zone (see page 114). It was reasoned that geomorphic features might co-occur in these areas; where there is a beach today, there may have been a beach in the past. Along rockier shorelines, there may be a lack of significant sedimentary features. However, where pocket beaches, tombolos, and fan deltas occur on predominately rocky shorelines, there is a greater likelihood of human settlement. In this manner, areas for survey can be narrowed down quickly in rocky areas, whereas shorelines that are sediment-rich may have considerably more area that is suitable for human habitation. Based on this criterion, most areas selected for mapping have mapped sediments along the predominately rocky shoreline of the Dundas Islands.

Creating Palaeo-Shoreline Maps for Field Investigations

Palaeo-shoreline maps were generated from the 2 m contour data for each of the eight mapped areas (Figure 53 and Figure 54). Palaeo-shoreline maps were created by choosing the 6, 10, and 14 m abl contours and deleting all contours below these elevations. These elevations were selected based on the results of “Chapter VI - Dundas Island Archipelago Late Pleistocene and Holocene Sea Level History”. There are multiple lines of evidence for an early Holocene stillstand in the region around 6 m abl. At the Pleistocene-Holocene boundary, the upper intertidal zone was 10 m abl. Approximately 12,000 BP, sea levels were higher than 13 m.

Conclusion

In order to focus archaeological prospection, this chapter has described physical, biological, and archaeological data that are considered to be significant with regard to potential for early archaeological site locations. Important to these data was the acquisition of a microtopographic digital elevation model from which palaeo-shoreline maps could be generated. A total of eight different coastal areas of the Dundas Island Archipelago were chosen for the creation of these maps.

With the generation of these maps, specific landforms could be targeted at different elevations; for example, areas that appeared as raised tombolos or flat topped terraces associated with alluvial fans. These areas were then selected for field investigations oriented at finding archaeological sites. The methods and results of archaeological prospection are presented in the following chapter.

Figure 53. Palaeo-shoreline maps created for northern Melville Island, 2 m contour interval above current intertidal zone.

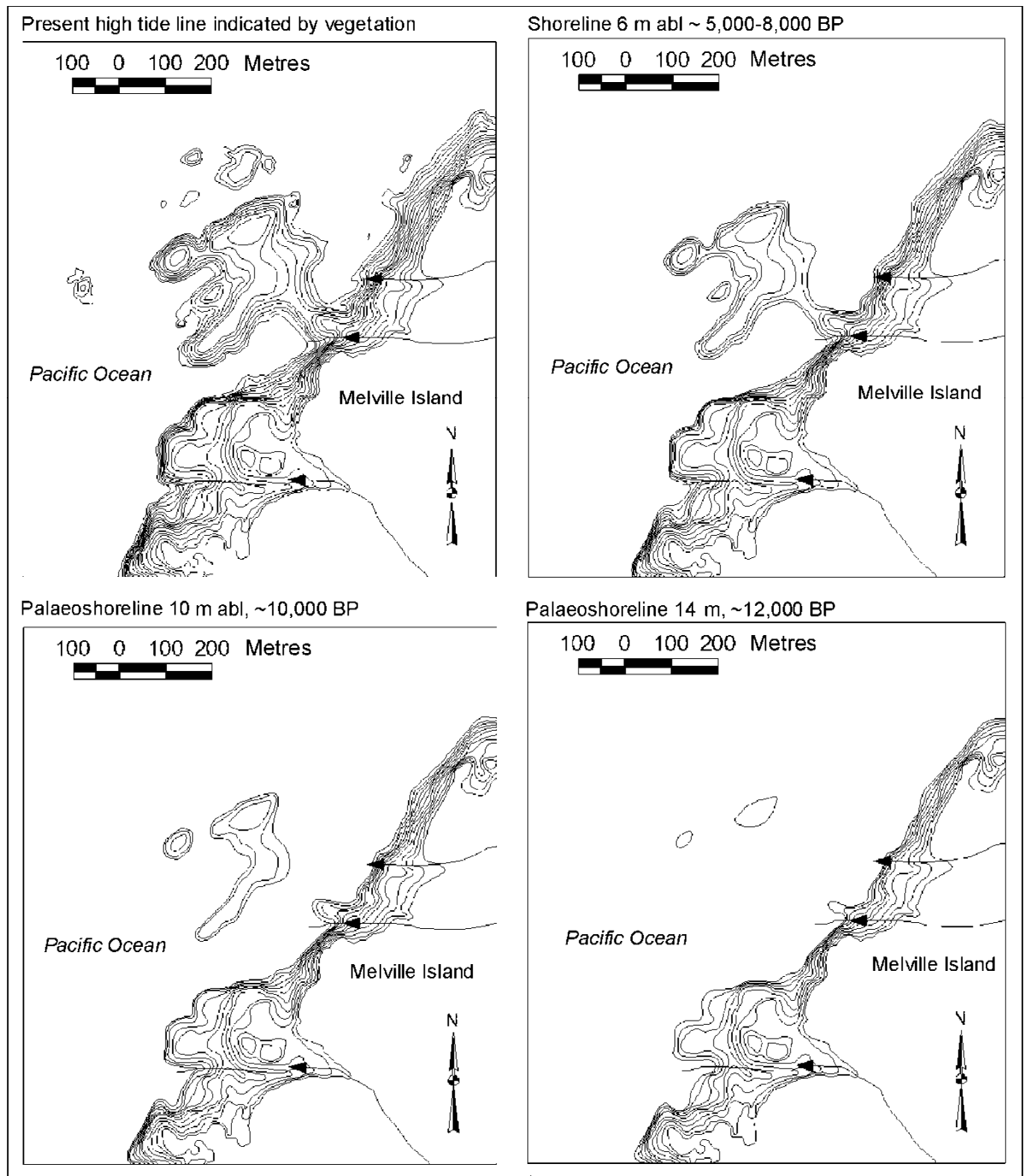
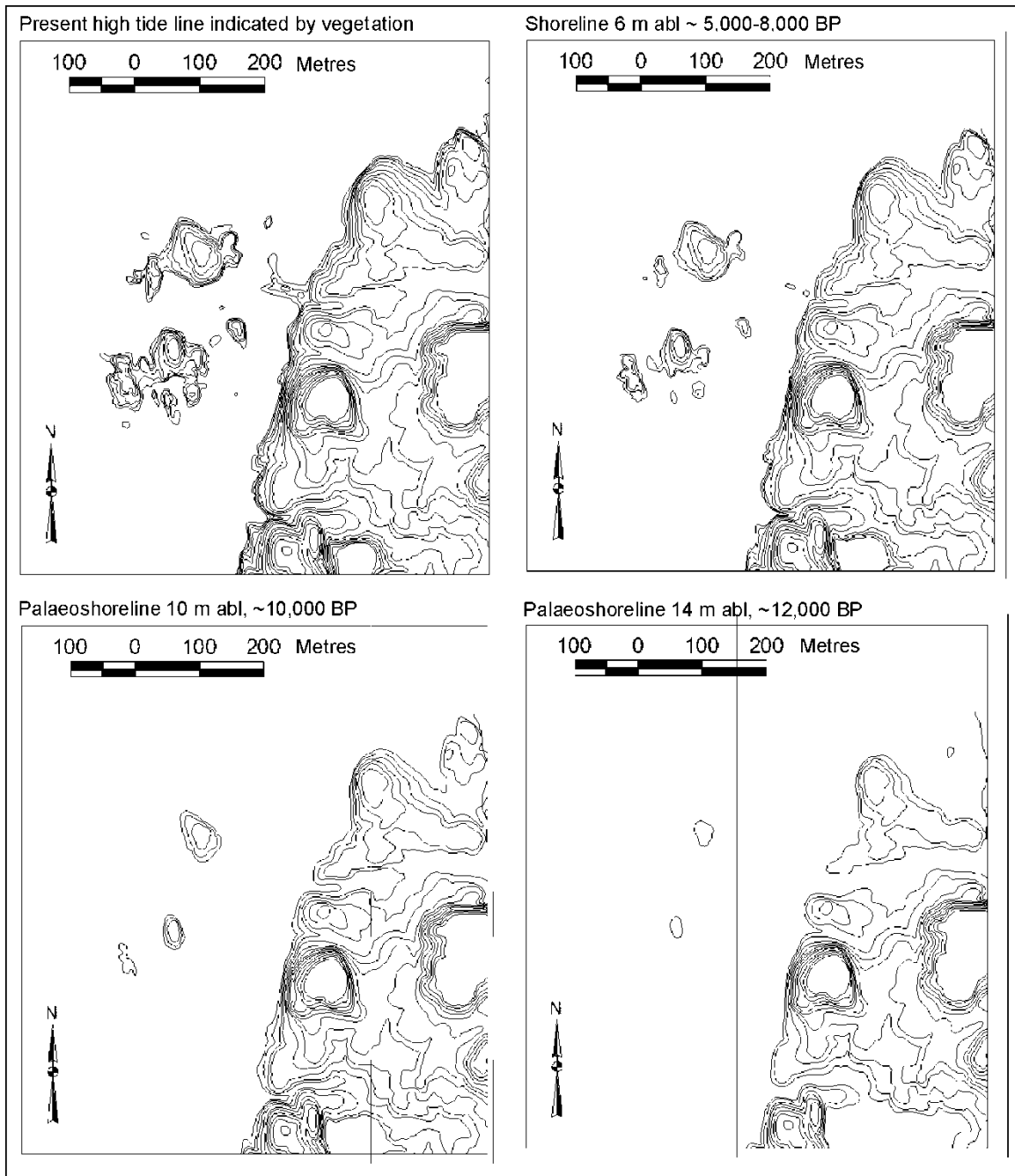


Figure 54. Palaeo-shoreline maps created for western Dunira Island, 2 m contour interval above current intertidal zone.



Chapter VIII – Archaeological Prospection Undertaken on Raised Marine Landforms on the Dundas Island Archipelago

The primary goal of this dissertation research project was to locate archaeological sites dating to the late Pleistocene and early Holocene on relict shorelines in the Dundas Island Archipelago. Before intensive archaeological field investigations were undertaken, data were collected to build a sea level curve for the study area and identify raised shoreline landforms as described in “Chapter VI - Dundas Island Archipelago Late Pleistocene and Holocene Sea Level History”. Two-metre contour maps from selected parts of the study areas were mapped between the vegetation line (~2 m abl) and 32 m abl. After integrating these data and producing maps for field surveys, archaeological prospection was undertaken in 2004, 2005 and 2006. The most intensive season of archaeological prospection and excavation occurred in 2006 over six weeks. Intensive field investigations covered only a small sample of the total area covered in the 2 m contour maps. However, all of the mapped areas (A through H) were visited at least once.

A field methodology was employed with the following goals in mind:

- 1) To find inland archaeological deposits between 6 and 20 m abl and inland of the current shoreline.
- 2) To undertake subsurface testing of archaeological deposits.
- 3) To acquire radiocarbon samples from the archaeological sites for dating the deposits.
- 4) To excavate one archaeological site from a raised marine context.

Methods

Two complementary methods were employed for site discovery: surface inspection and subsurface testing. Surface inspection was conducted prior to undertaking subsurface testing. Surface inspection involved traversing the area while examining exposures for archaeological material. Key exposures included creek cut banks, intertidal zones, and tree throws. Indeed, many of the archaeological sites found on raised terraces in Gwaii Haanas were identified from tree throws or from washed-out lithics in the intertidal zone (Fedje and Christensen 1999; Fedje et al. 2005a). Notes were also kept regarding potential raised marine geomorphic features while undertaking traverses.

Oakfield probing (2 cm diameter), Dutch augering (5 cm diameter), environmental soil probe (ESP) coring (2 cm diameter) and shovel testing (40 x 40 cm) were used in areas with potential for archaeological remains based on map data and surface inspection. Probing is the most efficient method for finding shell midden deposits but is not particularly useful for finding non-shell deposits although charcoal concentrations can be identified. Auger testing is an efficient means of determining soil depths and sediment types, shell middens, and charcoal concentrations. ESP coring was used to gain stratigraphic sediment sections in clear plastic tubes. Shovel and trowel testing was used to recover larger amounts of buried materials. Sediments excavated in auger and shovel tests were screened through 3 mm mesh or hand sorted to identify cultural material and matrices such as lithics, faunal remains (shell), charcoal, and fire-cracked rock. In some instances, samples excavated from these tests were collected. Macrofossil remains were selected from clear plastic ESP cores, and column samples from shovel and trowel tests were used preferentially for dating features.

In some instances where archaeological suspected deposits were found, 50 x 50 cm or 1 x 1 m units were excavated. These controlled units were excavated to aid in evaluating the nature of cultural deposits in the area and to acquire samples of artifacts, faunal remains, sediments, and material for radiocarbon dating. All sediments were water screened through a 3 mm mesh. Vertical profiles of each unit were carefully drawn and photographed. The location of each unit was mapped. Where significant cultural remains were encountered, column samples of cultural-bearing and associated strata were taken for analysis. All tests were backfilled.

The analyses of samples collected from archaeological contexts focussed on the identification and documentation of materials and their association with archaeological complexes and traditions of the region. Radiocarbon samples were sent to an appropriate lab to date the cultural-bearing strata. Rebecca Wigen at Pacific Identifications, Inc. (University of Victoria) identified, and supervised my identifications of the faunal remains.

A concurrent archaeological inventory project was undertaken by Dr. Andrew Martindale of the University of British Columbia, and a shell midden coring and augering program was conducted by Natalie Brewster, a PhD student from McMaster University. Their research was successful in discovering numerous archaeological sites in the vicinity of the present shoreline. In some instances, they also noted that shell midden deposits were found to extend far inland to, and over, elevations considered to be important for relict shoreline features. Their coring and augering methodology found that some of these raised landforms were predominantly massive back midden ridges up to 6 m deep. Midden ridges are features common to large shell midden-rich village sites on the

Northwest Coast. In other instances, elevated cultural deposits were found to be resting on sedimentary or bedrock features above 6 m a.s.l. In consideration of my research question, Martindale sampled shell fragments from ESP tubes taken from these higher elevation features and sent them for radiocarbon analysis. Their auger and probe methodology is similar to that of Cannon (1999), which was successful in locating and testing early and late Holocene shell midden sites on the central coast of British Columbia. Similar to the Dundas Islands, this central coast area around Namu may be an area where sea levels have been fairly stable since 10,000 BP (Cannon 1999).

Radiocarbon samples were sent to three different labs: Isotracer (TO) at the University of Toronto, University of California Irvine (UCIAMS), and Beta Analytic Inc. (BETA) in Florida. Some of the samples sent were marine shell. The effects of circulating marine carbon can change through time, necessitating the need to calibrate marine specimens with terrestrial specimens. Corrections used in this chapter for the marine reservoir effect are based on the work of Southon and Fedje (2003) who suggest:

the modeled and measured data for the environs of Haida Gwaii indicate a ca. 600-year-marine reservoir correction should be applied for Holocene times, possibly increasing to ca. 700 years after ca. 500 BP [Southon and Fedje 2003: 102].

This estimate used by Southon and Fedje (2003) of 600 years is used in this chapter unless otherwise noted.

Combined these methods were enacted to find and test archaeological sites associated with relict sea levels.

Results

All areas were accessed by small motorboat from a base camp in Hudson Bay Passage. Crew size varied from 2 to 4 individuals. A far greater area was mapped with 2 m contours than could be effectively and intensively surveyed and prospected. Intensities of fieldwork in different areas were the result of different factors: selection of area based on map data, ease and efficiency of access from the base camp in Hudson Bay Passage, and the results of preliminary investigations.

In this chapter, a map of survey traverses, landscape features, and archaeological sites is presented for each area that was mapped with 2 m contours ('Area A' through 'Area H'). These maps and related descriptions are given below for each area and are ordered from north to south.

Thirty AMS radiocarbon samples from archaeological deposits were sent for analysis by Dr. Andrew Martindale and myself (Table 12).

Brundige Inlet, northern Dundas Island, Area A

The Brundige Inlet area was the furthest of the mapped areas from our base camp in Hudson Bay Passage. During survey work, the isthmus that separates Goose Bay from Brundige Inlet was auger tested and it was determined that this was likely a relict tombolo feature (see "Chapter VI - Dundas Island Archipelago Late Pleistocene and Holocene Sea Level History"). The remains of a small cabin were found on the Brundige Inlet side of this feature; this cabin was previously recorded as GdTr-5 (Haggarty 1987b) (Figure 55).

Table 12. Details of radiocarbon dates from archaeological contexts in the study area. Marine reservoir correction is 600 years based on Southon and Fedje (2003).

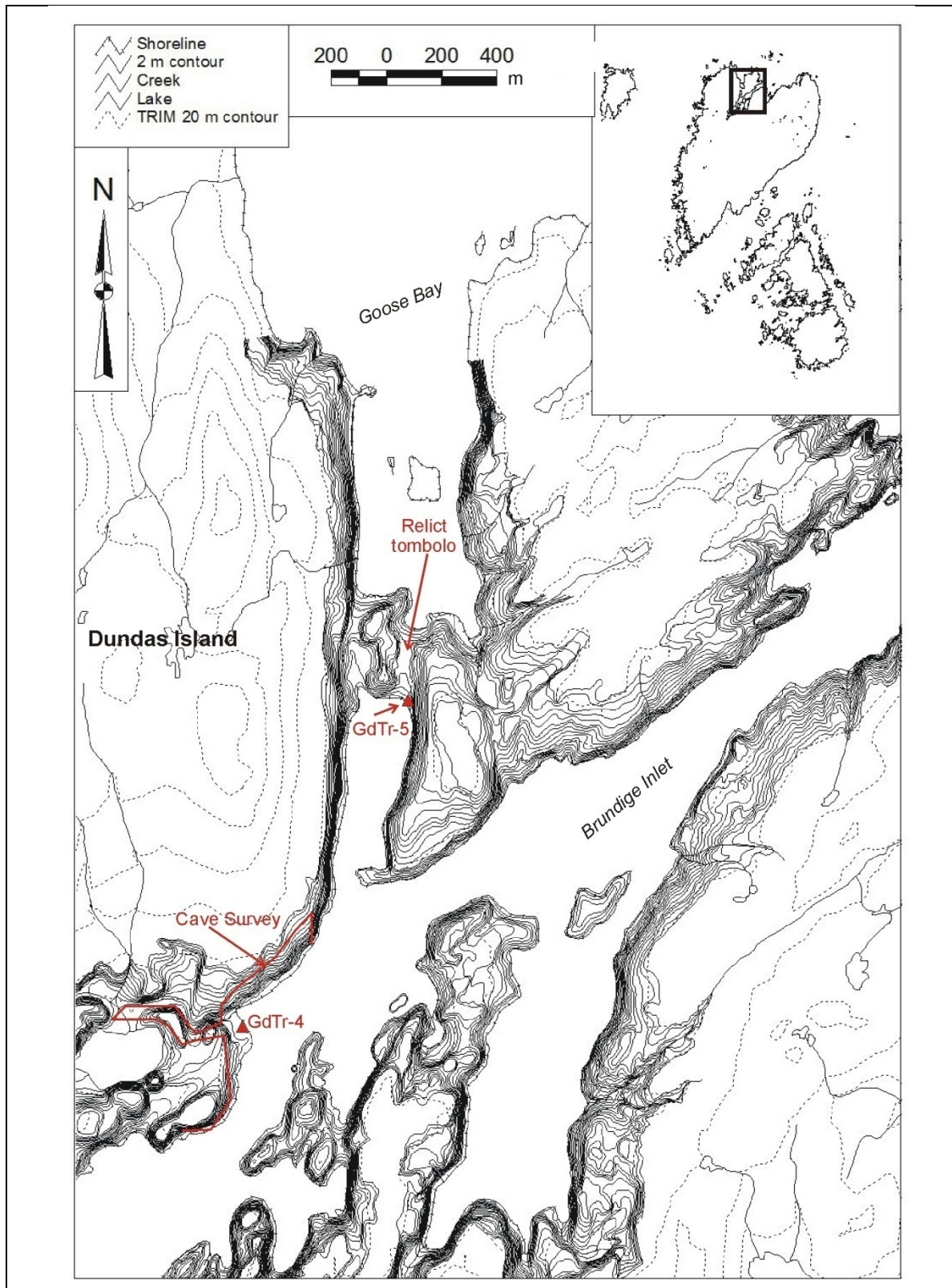
AMS lab #	Sample location	Sample elevation abt (m)	$\delta^{13}\text{C}$ (‰)	$^{13}\text{C}/^{12}\text{C}$	^{14}C age (BP)	^{14}C +/-	Material	Marine reservoir corrected (BP)	Proxy indicators	Sampled and Submitted by	Comment
UCIAMS 21983	GcTr-7	16	-25		640	60	Charcoal	N/A	Anthropogenic deposits	McLaren	ESP core of midden deposits
UCIAMS 21880	GcTr-7	16	-3.2		1,395	15	Mussel shell	795	Anthropogenic deposits	McLaren	ESP core of midden deposits
UCIAMS 21987	GcTr-3	3.8	-25		1,815	35	Seeds	N/A	Anthropogenic deposits	McLaren	ESP core of midden deposits
BETA 215182	GdTr-5	10		-3.1	2,390	40	Shell	1,790	Anthropogenic deposits	Martindale	First contact of shell in auger
BETA 215181	GdTq-1	12.75		-3	2,440	50	Shell	1,840	Anthropogenic deposits	Martindale	First contact of shell in auger
TO 13288	GcTr-8	11.28			2,510	50	Butter/horse clam	1,910	Anthropogenic deposits	Martindale	Upper midden deposits
UCIAMS 28010	GcTr-4	7.5	-25		2,530	15	Charcoal	N/A	Possible anthropogenic deposits	McLaren	Sample from hearth like feature found above beach with high density of intertidal lithics.
BETA 215175	GdTr-5	4.5		-.03	3,070	40	Shell	2,470	Anthropogenic deposits	Martindale	ESP core of midden deposits
UCIAMS 21883	GcTr-6	4.5	-0.5		3,145	20	Clam shell	2,545	Anthropogenic deposits	McLaren	ESP core sample on 5 m terrace.
TO 13291	GcTq-4	6.25			3,170	50	Butter/horse clam	2,570	Anthropogenic deposits	Martindale	Upper midden deposits
BETA 215177	GcTr-3	5.75		-1.2	3,460	40	Shell	2,860	Anthropogenic deposits	Martindale	ESP core of midden deposits

AMS lab #	Sample location	Sample elevation abt (m)	$\delta^{13}\text{C}$ (‰)	$^{13}\text{C}/^{12}\text{C}$	^{14}C age (BP)	^{14}C +/-	Material	Marine reservoir corrected (BP)	Proxy indicators	Sampled and Submitted by	Comment
UCIAMS 21985	GcTr-6	3.25	-25		3,645	25	Charcoal	N/A	Anthropogenic deposits	McLaren	ESP core sample on 5 m terrace.
UCIAMS 28011	NMCK	15.75	-25		3,880	20	Charcoal	N/A	Possible anthropogenic deposits	McLaren	Excavation unit excavated on 16 m terrace. Thick charcoal layer found in grey silt. Charcoal possible due to natural burn.
UCIAMS 21882	GcTr-6	3.25	-4.4		4,200	15	Clam shell	3,600	Anthropogenic deposits	McLaren	ESP core sample on 5 m terrace.
BETA 215176	GcTr-3	5.5		-1.8	4,440	50	Shell	3,840	Anthropogenic deposits	Martindale	ESP core of midden deposits
BETA 215174	GdTq-1	8.5		-0.2	4,780	40	Shell	4,180	Anthropogenic deposits	Martindale	ESP core of midden deposits
BETA 215183	GdTq-3	10.5		-5.9	5,230	60	Shell	4,630	Anthropogenic deposits	Martindale	First contact of shell in auger
BETA 215179	GcTq-4	7.5		-1.7	5,290	40	Shell	4,690	Anthropogenic deposits	Martindale	ESP core sample.
UCIAMS 30932	GcTr-6	10.39 - 10.34	-25		6,185	20	Charcoal	N/A	Anthropogenic deposits	McLaren	Excavation unit column sample at top of obvious shell bearing strata (shell midden).
UCIAMS 28009	GcTq-2	11.5	-25		6,390	20	Charcoal	N/A	Anthropogenic deposits	McLaren	Excavation unit on 12 m terrace found in association with light grey silts, charcoal, and 2 cobble choppers.
UCIAMS 30931	GcTr-6	8.94-8.89	-25		6,490	20	Charcoal	N/A	Anthropogenic deposits	McLaren	Excavation unit column sample at midpoint of obvious shell bearing strata (shell midden).
TO 13292	GcTr-6	8.34-8.39	-25		6,800	60	Charcoal	N/A	Anthropogenic deposits	McLaren	Basal deposits
BETA 215178	GcTq-4	12.25		-0.7	6,830	70	Shell	6,230	Anthropogenic deposits	Martindale	ESP core sample.

AMS lab #	Sample location	Sample elevation abt (m)	$\delta^{13}\text{C}$ (‰)	$^{13}\text{C}/^{12}\text{C}$	^{14}C age (BP)	^{14}C +/-	Material	Marine reservoir corrected (BP)	Proxy indicators	Sampled and Submitted by	Comment
BETA 215180	GdTq-3	8.25		-1.2	6,890	50	Shell	6,290	Anthropogenic deposits	Martindale	ESP core sample.
UCIAMS 21984	GcTr-6	8.5	-25		6,925	50	Charcoal	N/A	Anthropogenic deposits	McLaren	ESP core sample on 11 m terrace.
UCIAMS 30930	GcTr-6	8.49-8.44	-25		6,940	20	Charcoal	N/A	Anthropogenic deposits	McLaren	Excavation unit column sample at bottom of obvious shell bearing strata (shell midden).
TO 13289	GcTr-8	6.7			7,000	60	Butter/horse clam	6,400	Anthropogenic deposits	Martindale	Basal shell midden
UCIAMS 31730	GcTr-6	8.44-8.34	-16		7,300	30	Whale bone artifact	Unknown	Anthropogenic deposits	McLaren	Excavation unit AA. Bone has been shaped. Sample was brown in color even after a base treatment to extract possible humic contamination. The ultrafiltered and freeze dried gelatin extract was also brown rather than white or light tan. This suggests that carbohydrates or other exogenous chemical groups may have covalently bonded to the collagen (J. Southon personal communication).
UCIAMS 21881	GcTr-6	8.5	-4.8		7,510	20	Mussel shell	6,910	Anthropogenic deposits	McLaren	ESP core sample on 11 m terrace.

AMS lab #	Sample location	Sample elevation abt (m)	$\delta^{13}\text{C}$ (‰)	$^{13}\text{C}/^{12}\text{C}$	^{14}C age (BP)	^{14}C +/-	Material	Marine reservoir corrected (BP)	Proxy indicators	Sampled and Submitted by	Comment
UCIAMS 28008	GcTr-6	8.34-8.29	-25		9,690	30	Charcoal	N/A	Anthropogenic deposits	McLaren	Excavation unit. Sample taken from brown stained silty sediments in bottommost column sample. According to photographs and profiles this is the colour of the basal most deposits sitting on bedrock. Also found in sediments: sea mammal bone fragments, mussel shell, urchin spines, and charcoal.

Figure 55. Archaeological survey undertaken in Brundige Inlet, Area A.



Hutchison (1982) mapped a unit of massive limestone along the northern shore of Brundige Inlet. This limestone was identified in the intertidal zone, and surveys for karst and cave features were conducted along the steep backshore area above the intertidal zone. A creek that flows from a small lake on the northeast side of Brundige Inlet was also surveyed for cave features, as limestone was noted at the mouth of the creek (Figure 55). No caves or well-developed karst features were identified.

On the beach where this same creek empties into Brundige Inlet, lies a canoe run recorded by Haggarty as GdTr-4 (Haggarty 1987a). Intertidal lithics were noted including a core and a ground stone splitting adze. The ground stone adze was collected. As these remains are in the vicinity of the present shoreline and contain a ground stone implement they most likely date to the later Holocene times.

From the 2 m contour maps several distinct flat areas are visible above terrace-like formations at 14 m ahl and higher on the south side of Brundige Inlet (Figure 55). This shoreline was cruised by watercraft and much of the forest appeared to be stunted yellow cedar suggesting poorly drained landforms. This area warrants further investigation on foot.

Western Dundas Island, Area B and Area C

High-resolution contour maps were created for two areas on the western shore of the Dundas Islands (Figure 56 and Figure 57). Large sand beaches in the present day intertidal zone characterize both of these areas which are difficult to reach in small watercraft as swells tend to be large along the predominantly rocky shoreline of the west

Figure 56. Archaeological survey undertaken on west Dundas Island, Area B.

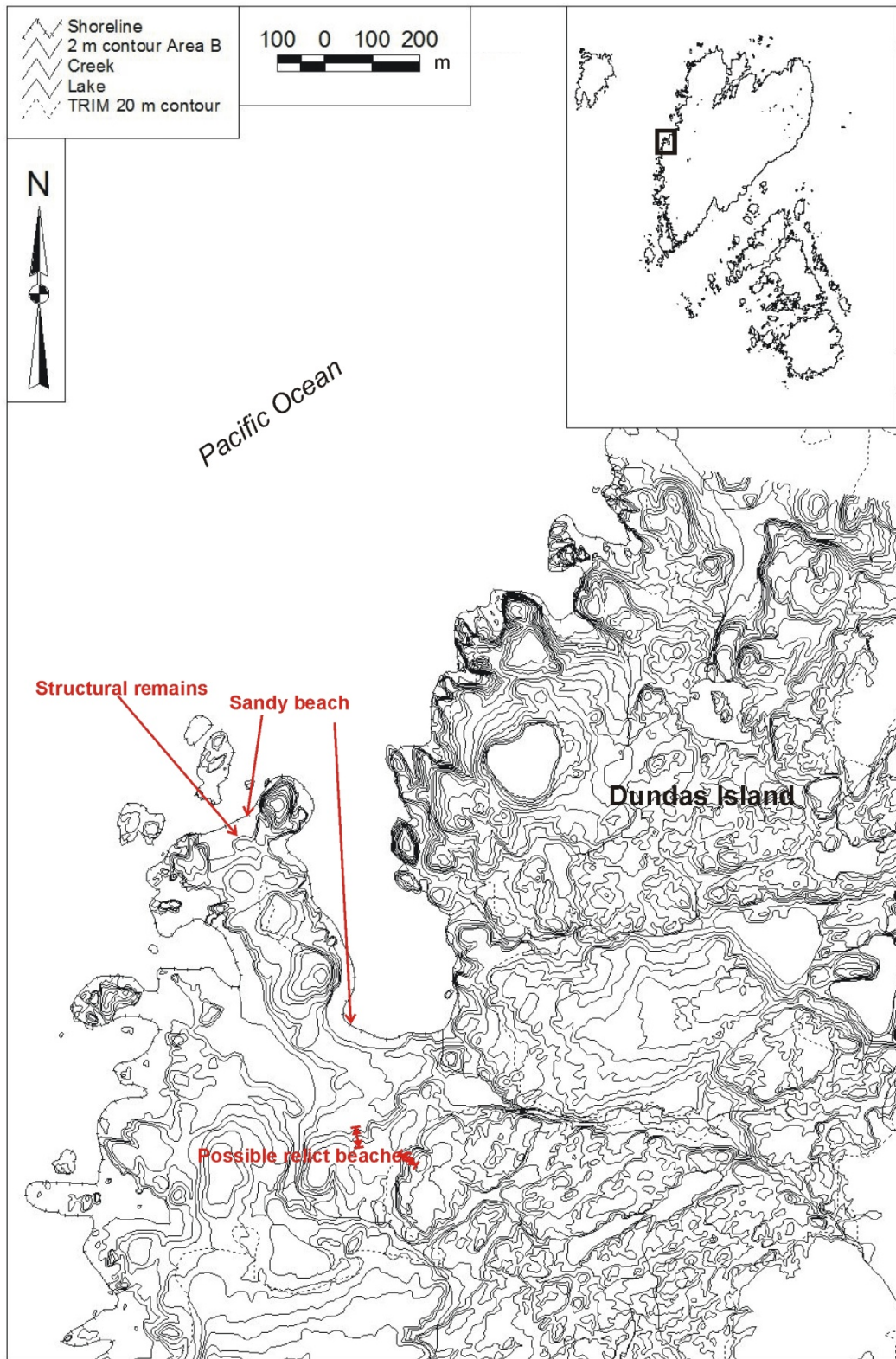
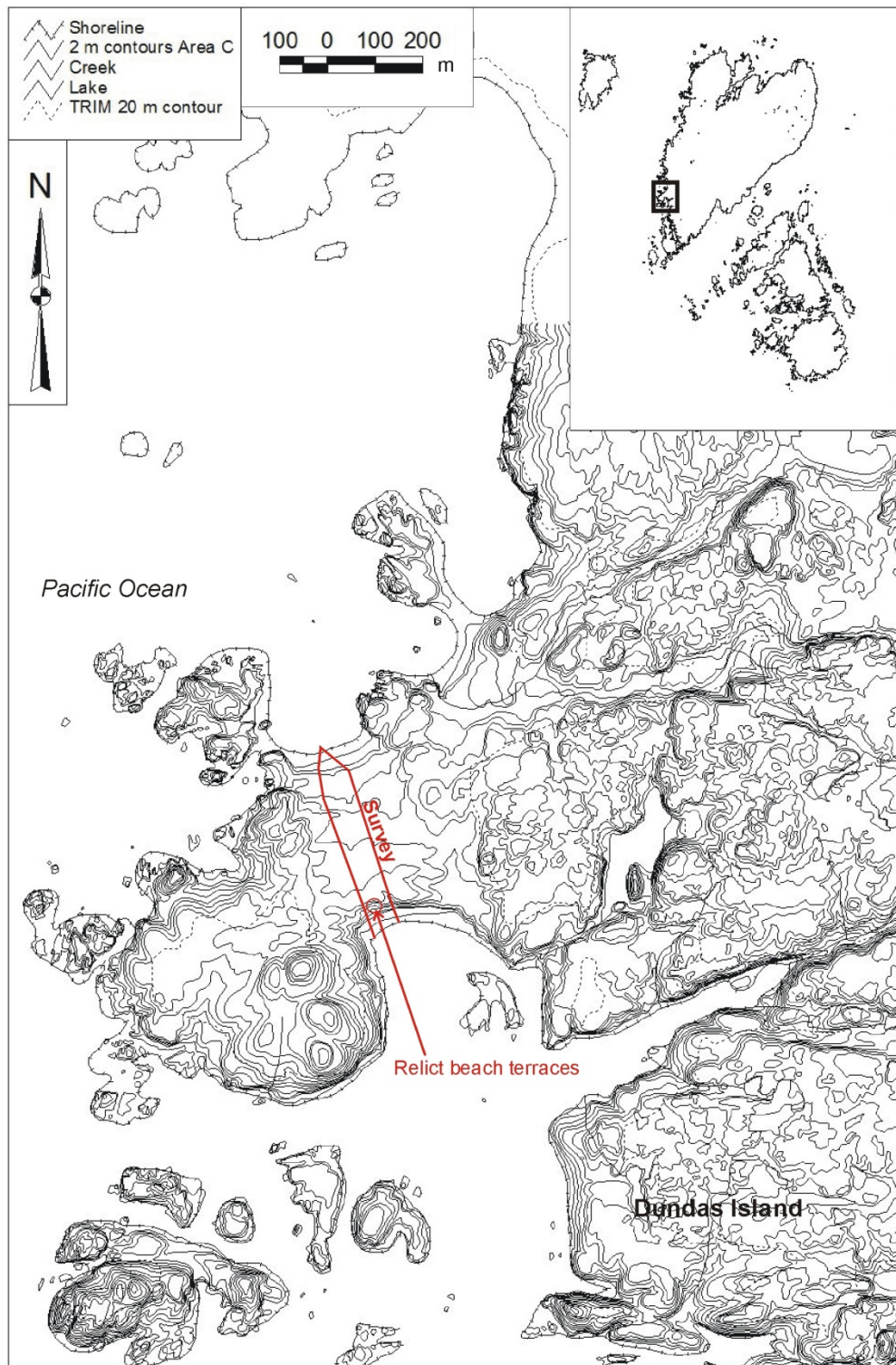


Figure 57. Archaeological survey undertaken on west Dundas Island, Area C.



coast. Due to difficulties in getting to these parts of the Islands, they were only visited briefly.

A large sand beach in a northwesterly facing bay characterizes the most northerly area mapped on the western side of Dundas Island. Here, lithics were found in the intertidal zone although none were collected. A vegetation stabilized dune/bar feature rises directly upslope of the beach vegetation line (Figure 56). Culturally modified trees were also noted in the area. Possible beach strandlines located directly to the south, between 6 m and 10 m abl and 12 and 16 m abl, were not surveyed, however, these features appear on the 2 m contour maps.

To the northwest, on a low-lying point, a white sand beach was noted from the boat (Figure 56). Just above the beach the remains of a cabin were spotted. A small islet that lies to the north of the point protects this area.

The more southerly area on the western side of Dundas Island for which 2 m contours were generated is characterized by an isthmus landform that connects a small islet to Dundas Island (Figure 57). Beaches on the north and south sides of this feature are sandy and it was thought that this feature might be a relict tombolo in a protected location. A brief visit to this feature was made and we traversed it from one side of the isthmus to the other. On the south side of this feature distinct beach strand lines were found at 6 m abl and 10 m abl. Augering at the top of the isthmus, 12 m abl, found beach sands below forest soils suggesting that the feature is a relict tombolo. We found the north side of this feature to be gently sloped and poorly drained. Archaeological deposits would be most likely to occur on the south side of this feature but archaeological testing was not undertaken at the time of our visit.

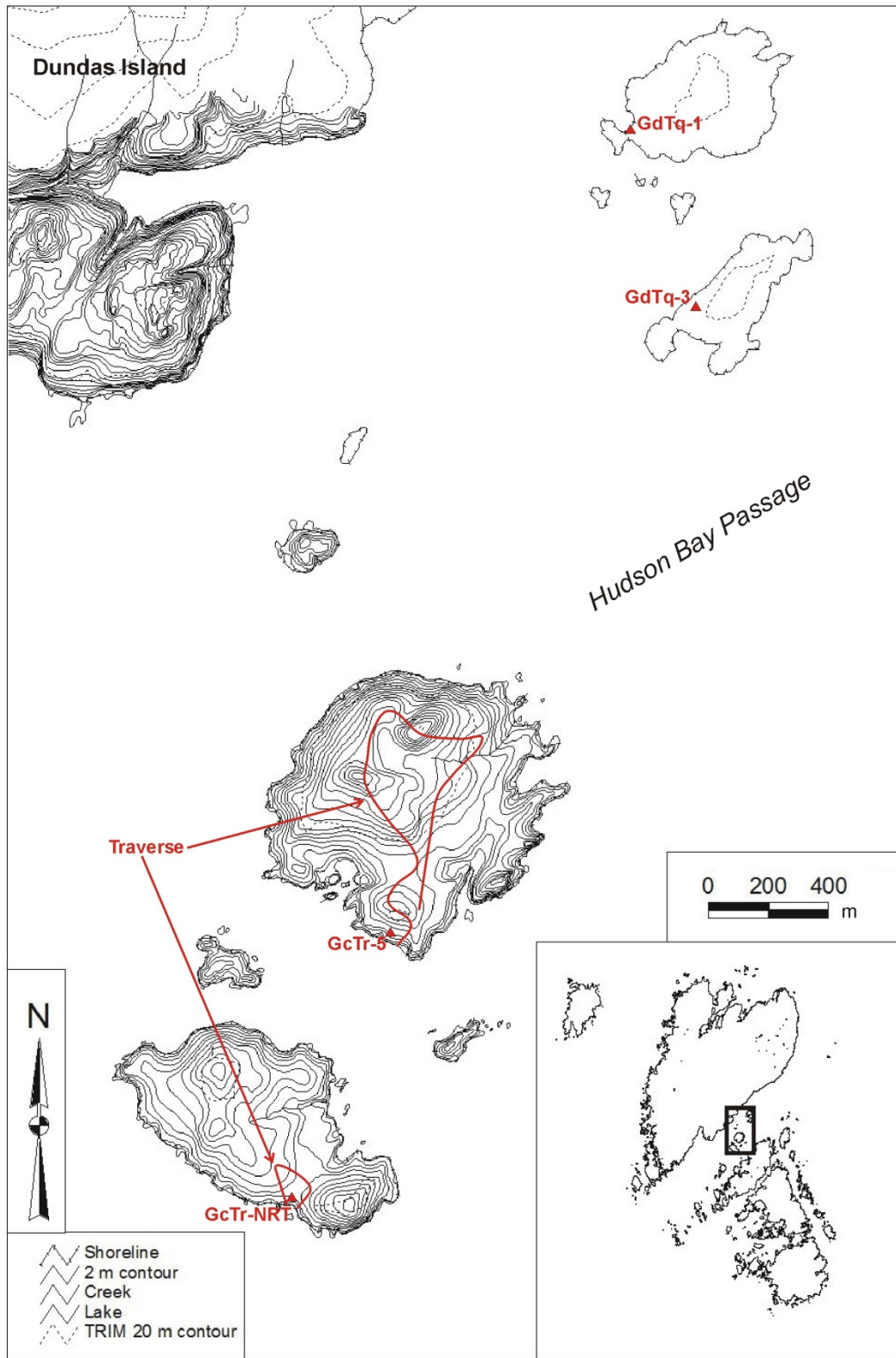
Northern Hudson Bay Passage, Area D

This area is located at the southern end of Dundas Island and includes the northern Nares Islets, which are situated in Hudson Bay Passage (Figure 58). This body of water is 3 km wide and located between Dundas and Baron Islands and is a major passage between Dixon Entrance to the west and Chatham Sound to the east. The southeastern shore of Dundas Island is rocky with some fan deltas at creek mouths. Overall, the shorelines of the Nares Islets are rocky and sedimentary features include tombolos, isthmuses, pocket beaches, and in some areas, intertidal flats. Two large village sites were found during previous archaeological investigations: GdTq-1 (Inglis 1975) and GdTr-5 (Haggarty 1988) (Figure 58).

GdTq-1

GdTq-1 is a large midden village site first recorded by Richard Inglis in 1975 (Inglis 1975). Directly behind the house pits at this site is a large midden ridge that rises to 11.5 m abl. ESP core and auger tests into this midden ridge were undertaken by Martindale and Brewster. Bottom and top dates, run on shell midden deposits from this high elevation landform, date between 4,780 \pm 50 BP (BETA 215174) and 2,440 \pm 50 BP (BETA 215181), corrected for marine reservoir effect to 4,180 and 1,840 BP. Below the shell midden, a black silt layer is visible in the ESP core tube taken from the site that may represent an earlier non-shell cultural stratum. The basal elevation for this midden ridge is estimated at 8.5 m abl. This anthropogenic feature, although located above the early Holocene still-stand, is the result of later Holocene household refuse being piled behind this large village site. I undertook some traverses on this island to measure the elevations of abrupt slope breaks and to search for archaeological deposits at higher

Figure 58. Archaeological survey undertaken in northern Hudson Bay Passage, Area D.

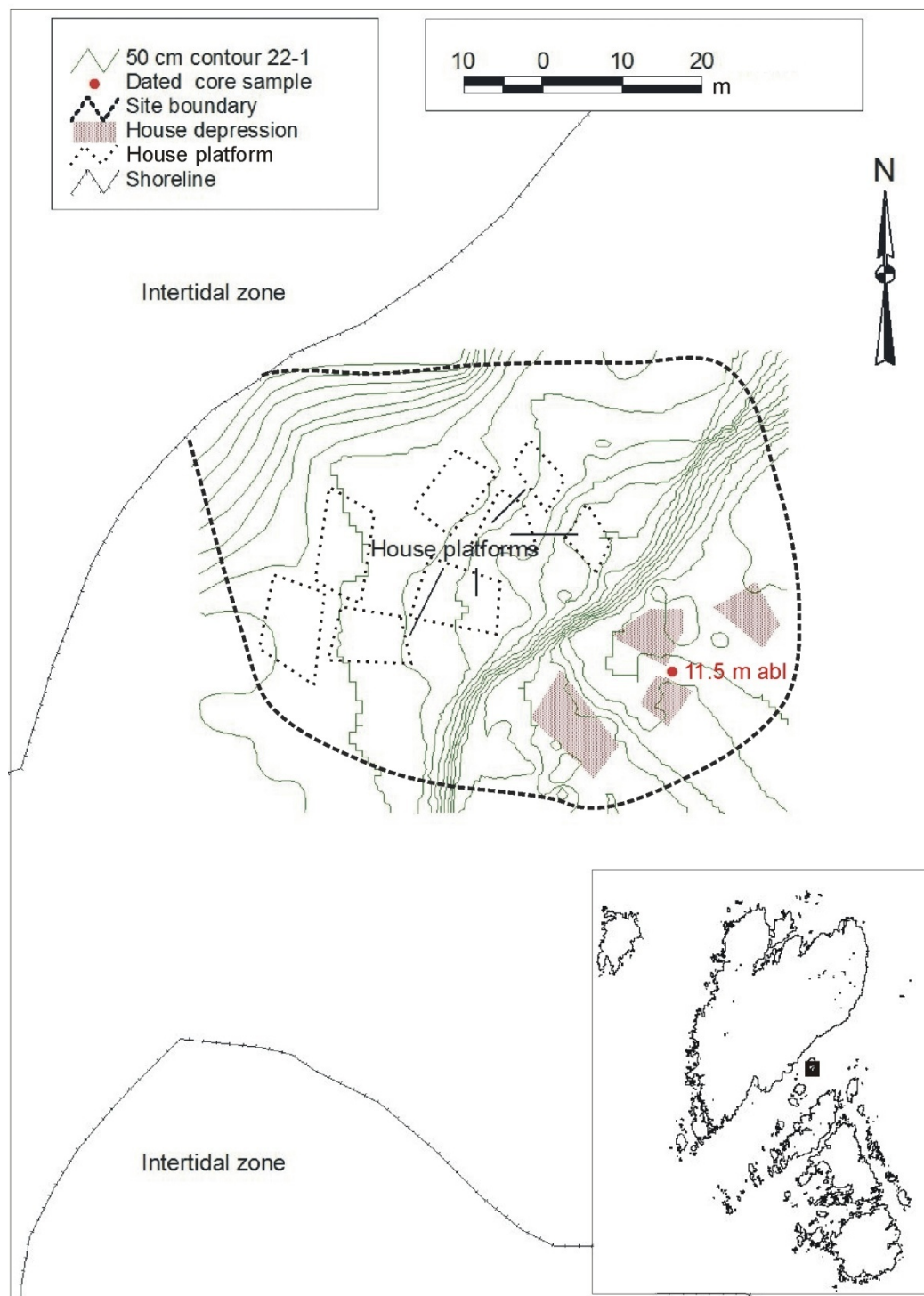


elevations. No further archaeological deposits were found on raised features. The measurements of abrupt slope breaks are described in “Chapter VI - Dundas Island Archipelago Late Pleistocene and Holocene Sea Level History”.

GdTq-3

On the northern Nares Islet that lies immediately south of GdTq-1 is a newly inventoried archaeological site, GdTq-3 (Figure 58 and Figure 59). At this location a shell midden, with eight house platforms, was discovered by Martindale and Brewster’s survey crew. Directly behind these structural remains is a steep vertical rise (rock bluff) to a shell midden topped terrace with four house-like depressions. The top of this terrace feature is 11.5 m abl and the bottom is approximately 6 m abl, it lies 40 m inland of the current shoreline. Auger and ESP core samples were taken from midden deposits on the top of the ridge by Martindale and Brewster’s crew. Shell midden was found to extend from beneath forest soils to a depth of 470 cm dbs. Further sediments were collected to 5.68 m dbs. Top and bottom dates were run on shell selected from these samples. These yielded an age for the bottom of 6,890 \pm 50 BP (BETA 215180) marine reservoir corrected to 6,290 BP, and for the top of 5,230 \pm 60 (BETA 215183) marine reservoir corrected to 4,630 BP. It is estimated that the basal deposits were approximately 8.3 m abl. This date and elevation are consistent with the sea level curve for the area, which suggests that there was a stillstand at 6 m abl, during the early Holocene. It likely that the terrace upon which these deposits sit was formed during the 6 m abl shoreline stillstand. Following the lowering of sea levels after this time, occupation appears to have shifted to lower areas, which likely post-date the occupation of this higher terrace.

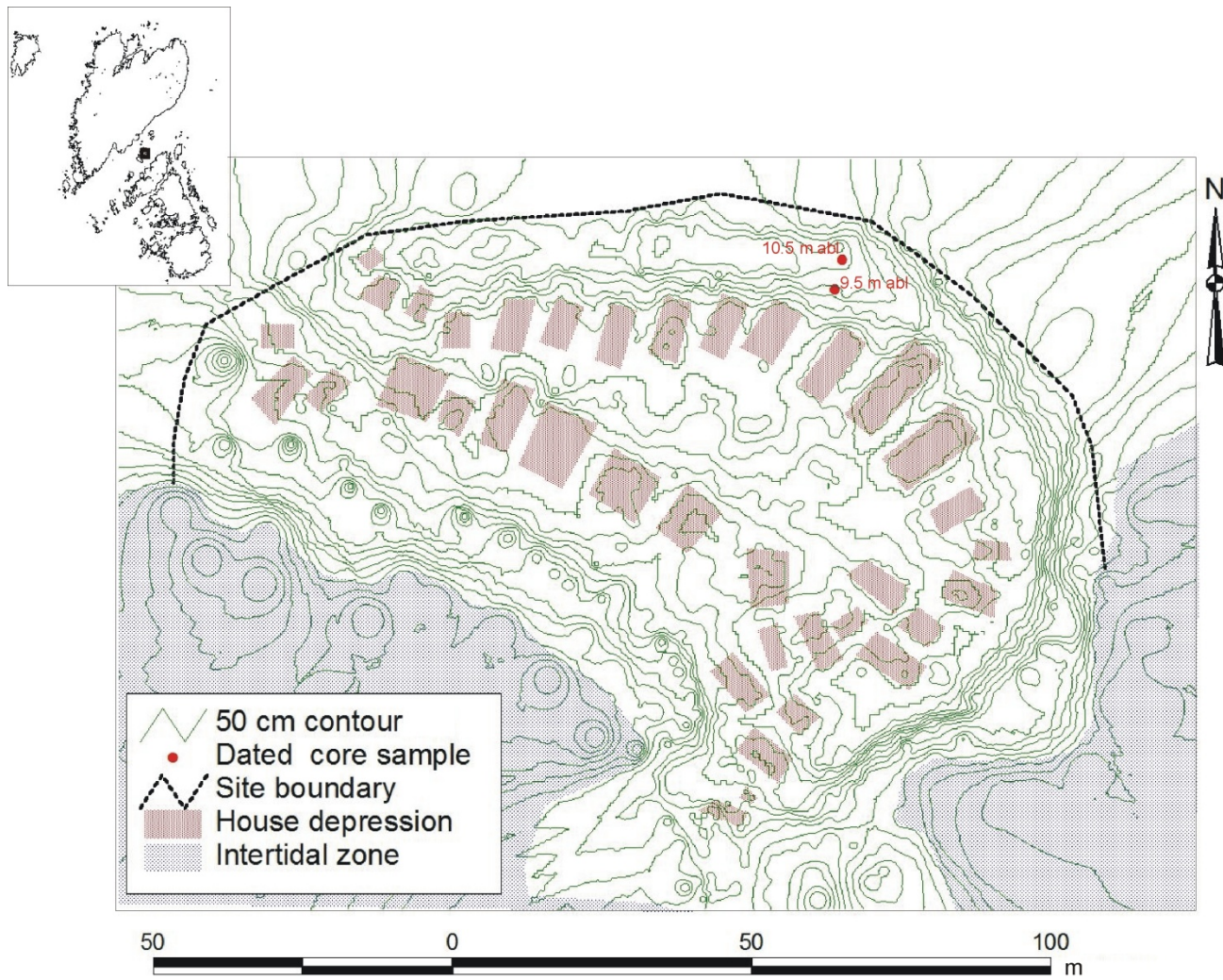
Figure 59. Map of archaeological site GdTq-3.



GdTr-5

GdTr-5 is large midden site with 37 house depressions in two rows originally recorded by Haggarty and his survey crew (Haggarty 1988). Directly behind the second row of houses is a large midden ridge that rises to 11 m abl (Figure 60). ESP core and auger tests into this midden ridge were undertaken by Martindale and Brewster. Deposits were dated between 3,070 \pm 50 BP (BETA 215175) and 2,390 \pm 50 BP (BETA 215182), which are corrected for marine reservoir effect to 2,470 and 1,790 BP. A distinct black silt matrix underlies the shell and may be an older cultural-bearing stratum. The basal elevation for sediments in this midden ridge is estimated at 4.5 m abl. I undertook survey and probe testing to sample sediments on higher landforms on the same island. No additional cultural remains were identified during this survey. Both the dates and basal elevation of the deposits reveal that the accumulation of anthropogenic matrices in this midden backridge occurred over a short period of time after sea levels were below 4.5 m abl. Auger and probe tests were conducted along this transect and revealed highly saturated soil underlain by bedrock.

Figure 60. Map of archaeological site GdTr-5.



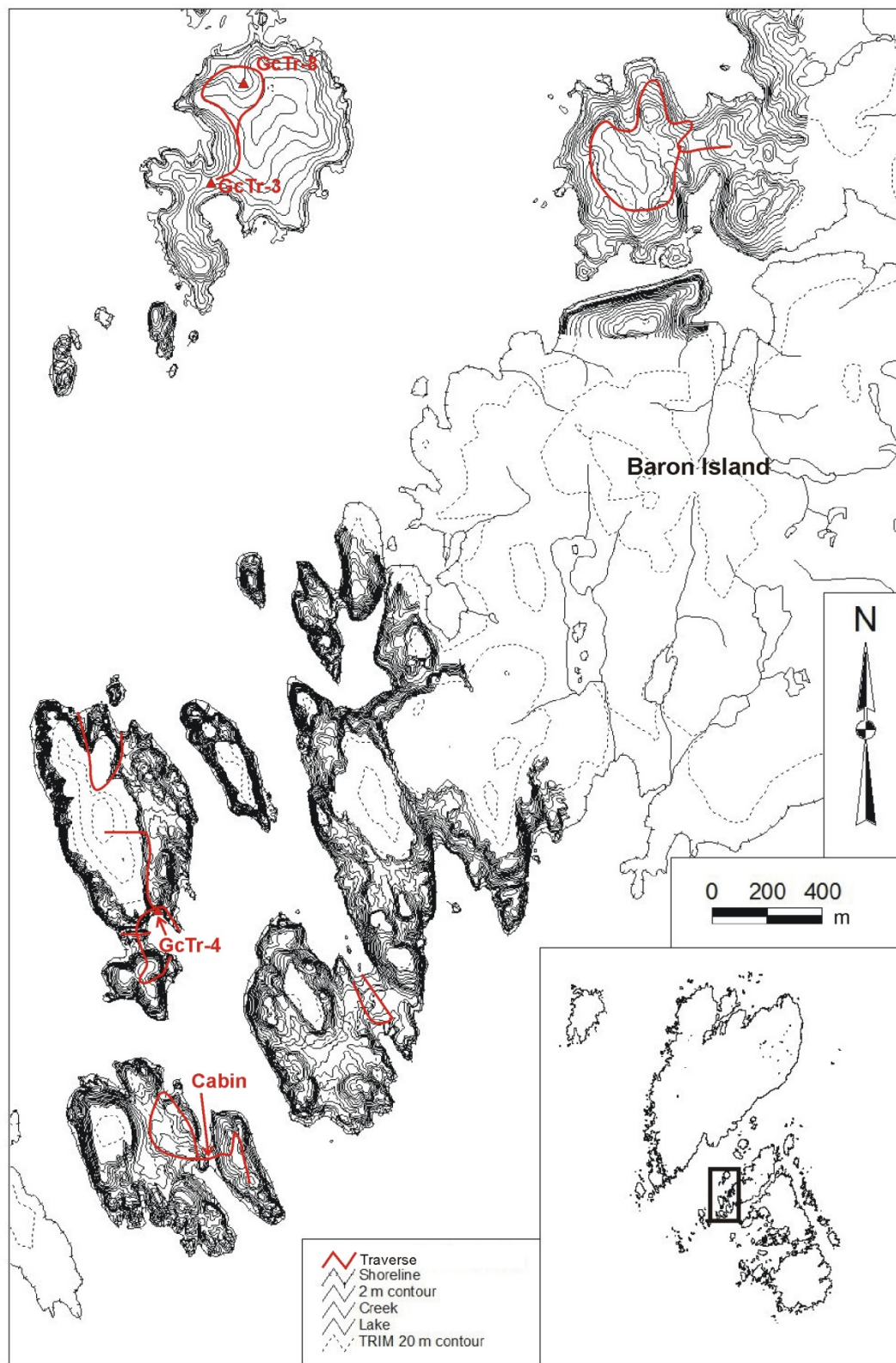
GcTr-NRT

On the island that lies to the south of GdTr-5, a raised tombolo feature, located at 6 m abl, is discernible on the 2 m contour map (Figure 58). This area was targeted with Oakfield probes and augers and shell midden deposits were found (GcTr-NRT). These deposits are located on a 6.4 m abl terrace and the front of the midden deposits are 16 m inland from the present day shore. No shell midden was found between the terrace and the shore. The depth of midden deposits was not assessed. This archaeological site is situated on a relict tombolo that formed during the early Holocene stillstand. Based on the sea level curve and shoreline position of this site, it is likely that this site post-dates 5,500 BP but predates 3,885 BP when sea levels dropped lower than 4 m abl. This site has not been mapped and no Borden number has been assigned to date.

Southern Hudson Bay Passage and West Baron Island, Area D

Included in this area, mapped with 2 m contours, are the southern Nares Islets, a portion of northern Baron Island, western Baron Island, and islands that lie to the west of Baron Island (Figure 61).

Figure 61. Archaeological survey undertaken in southern Hudson Bay Passage and western Baron Island, Area E.



GcTr-8

GcTr-8 is a large village site with 20 house depressions oriented in a horseshoe shape (Figure 62). The horseshoe shape surrounds a saturated, skunk cabbage rich, boggy area that was likely a small bay when sea levels were slightly higher. A large back midden ridge rises to 11 m abl. Auger and ESP core tests were taken at the top of this midden ridge by Brewster and Martindale. Top and bottom shell samples were selected and sent for dating. From the bottom sample a shell date of 7,000 \pm 60 BP (TO 13289) was obtained (8 m abl). This date, corrected for marine carbon reservoir effect, is 6,400 BP. From the top of this midden, a shell date of 2,510 \pm 50 BP (TO 13288) was obtained (11 m abl). This date, corrected for marine reservoir effect, is 1,910 BP. This date span suggests that the site was occupied during the early Holocene stillstand above 6 m abl. The basal date is estimated as coming from an elevation of 10 m abl. Black silt underlies the midden deposits, which grades into brown sand. This lower black silt may be non-shell cultural-bearing matrices. Occupied during the early Holocene stillstand, this landform continued to be used in the late Holocene, even though sea levels were well below the 6 m abl stillstand, as a back midden ridge where shell, and other refuse from the village below, was dumped.

GcTr-3

GcTr-3 is located on the same island as GcTr-8. This area is an isthmus that connects two islets forming one larger island (Figure 63). The landform is 10 m high and was targeted for subsurface testing using augers and Oakfield probes. Shell midden was found to extend below parts of this landform between the current shoreline and 9 m abl.

Figure 62. Map of archaeological site GcTr-8.

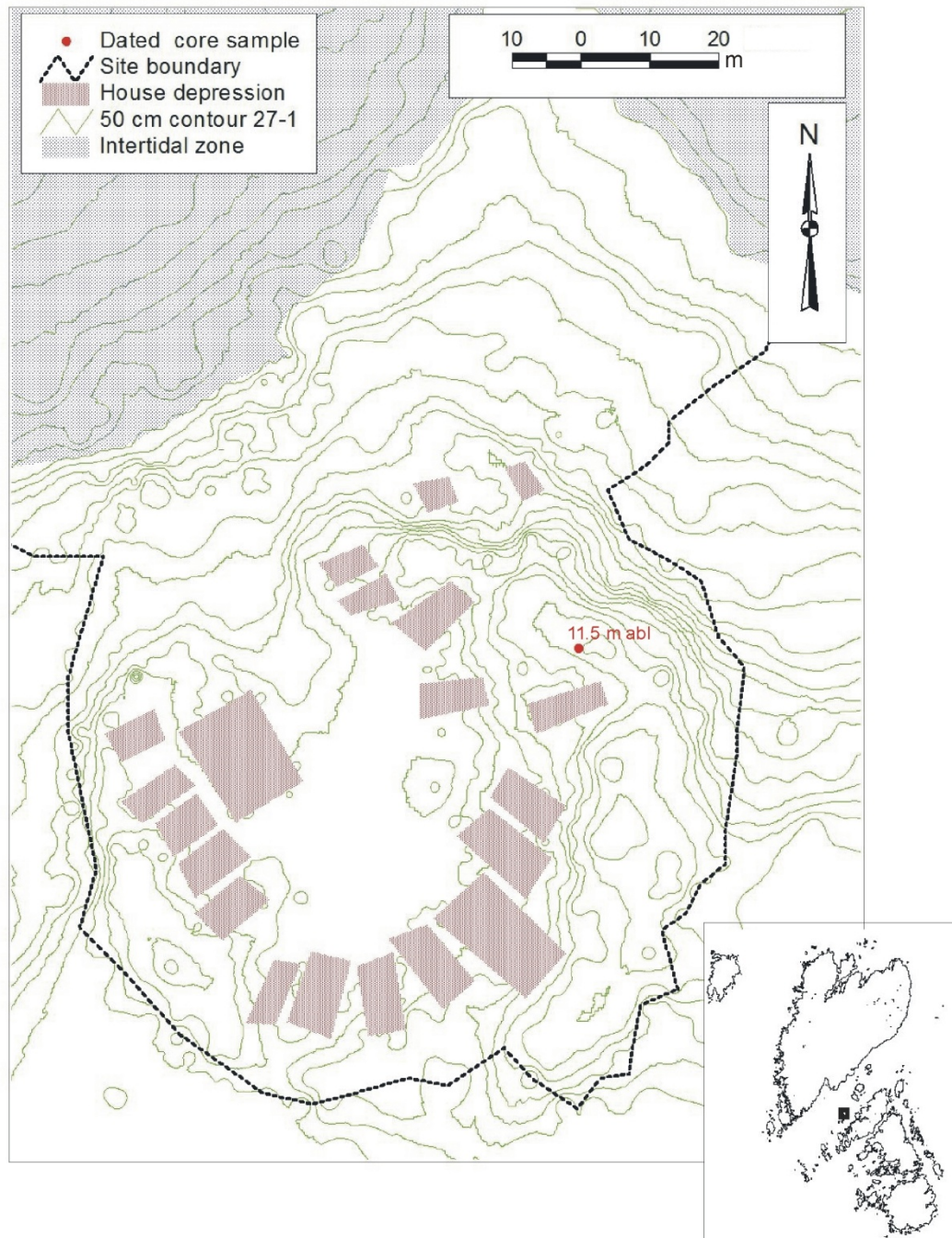
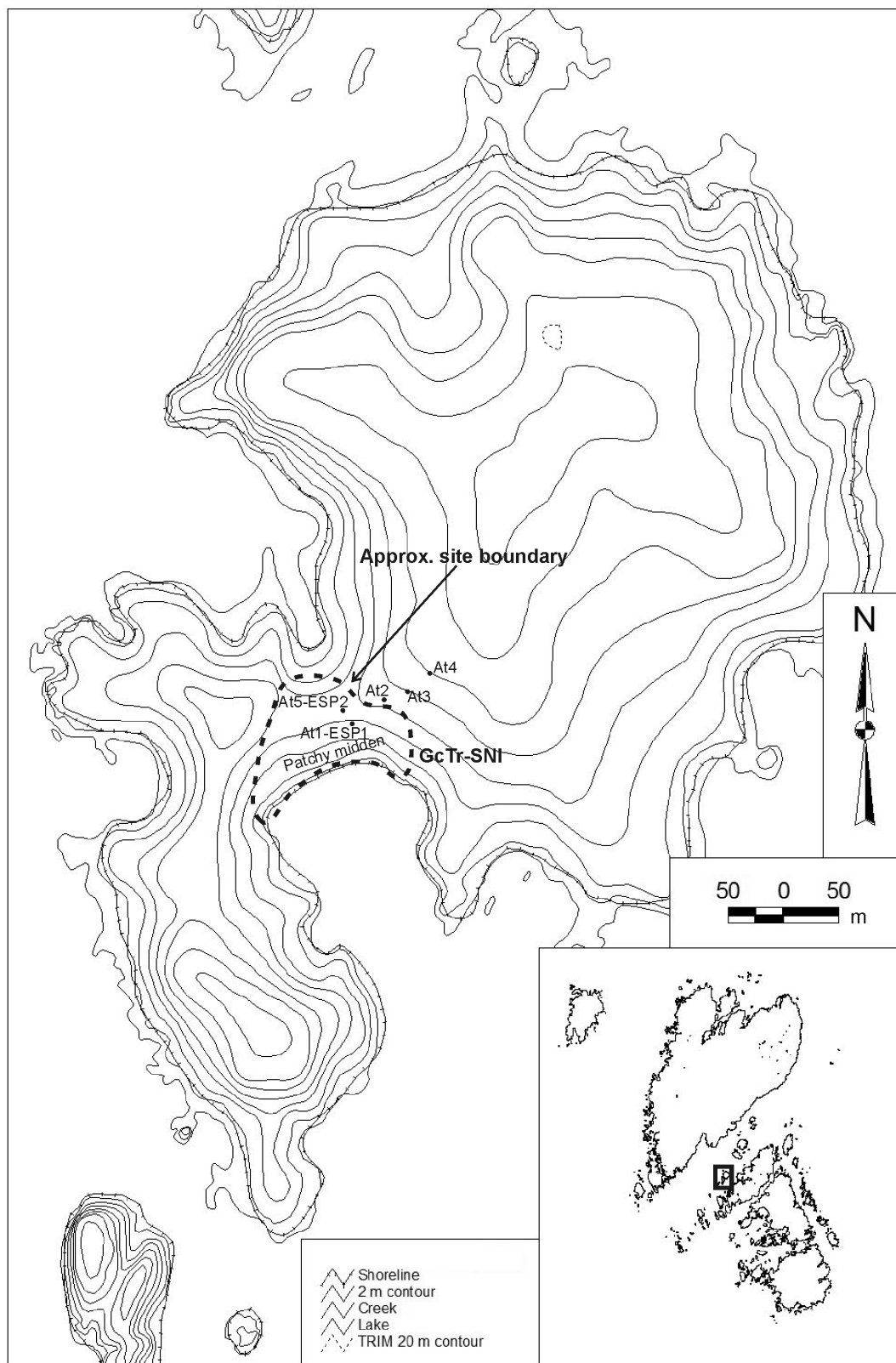


Figure 63. Map of archaeological site GcTr-3 (GcTr-SNI).



I undertook some augering of landforms above 10 and 16 m abl, but failed to reveal further shell midden deposits. Soils were found to be shallow and overlying bedrock and sand.

I conducted ESP core samples on midden-bearing landforms between 5 and 7.5 m abl. Midden deposits were found to 3.58 m below the 5 m abl test. During auger testing and in the ESP core tubes, lower levels appeared to have highly crushed shell with no apparent minerogenic input. In consideration of the possibility that non-cultural shell deposits do occur (Erlandson and Moss 2001), it was hypothesized this may represent shell hash from a raised biogenic beach. Biogenic beaches are found along the current shoreline on parts of the Dundas Islands. Some samples of these shells were analyzed in the lab and were found to lack water rolling and charcoal flecks were identified. Based on the results of this analysis, it is more likely that these shell deposits are culturally derived. A date was run on seeds from the top of midden deposits found 1.5 m below the 5 m abl core sample and returned at 1,815 \pm 35 BP (UCIAMS 21987). Top and bottom shell dates were run on shell samples from a test undertaken at 7.5 m abl by Martindale and Brewster. These yielded dates of 3,460 \pm 40 BP (BETA 215177), marine reservoir corrected 2,860 BP from the top of the midden deposits (5.85 m abl), and 4,440 \pm 50 BP (BETA 215176), marine reservoir corrected 3,840 BP, from the bottom (5.5 m abl). This information reveals that shell midden accumulated just above 5 m abl after sea levels had fallen from the 6 m abl stillstand. On the lower landform, the occupation is later, ending around 1,815 BP. One metre of midden deposits accumulated on this lower landform before this date and occupation of this part of the landform began at 2.5 m abl. This

record of occupation occurs well below the early Holocene stillstand and the dates from these deposits are vertically consistent.

Survey on Northwest Baron Island

To the west of the southerly Nares Islets, on the northwestern shore of Baron Island, a possible raised tombolo feature, with a maximum elevation of 10 m abl, was targeted by an inland probe and auger survey (Figure 61). This area was found to have poorly drained soils. Auger testing found marine clay below tests at 6 m abl and sand beneath tests undertaken to 10 m abl. Elevations were recorded by altimeter. I also undertook survey around the area that lies to the west of this isthmus. This traverse followed a prominent terrace top between 13 m and 14 m abl. However, this area has poorly drained soils and encroaching bog lands.

Auger and ESP core testing was undertaken on another raised tombolo feature located at the westernmost end of Baron Island (Figure 61). Results of this testing are discussed in “Chapter VI - Dundas Island Archipelago Late Pleistocene and Holocene Sea Level History”.

GdTr-4

The islands to the west of Baron Island are characterized by steep jagged cliffs in many places. My survey crew recorded archaeological deposits on the island immediately to the west of Baron Island and are recorded as GdTr-4 (Figure 64). Traverses for rock shelter features were undertaken on these islands. Two small rock shelters were noted beneath colluvial boulders at 6 m abl. These shelters seemed to be too small to be good refuges for human occupants. Shell noted on the floors of these shelters indicates that they have been used recently, possibly by river otters. A large rock shelter (west of

Baron rock shelter 1 – WOBRs 1) was found in an area directly above these smaller shelters, 20 m abl. This shelter measures 14 x 3.5 m under a bedrock outcrop (Figure 65 and Figure 66). An additional rock shelter, approximately 2 x 4 m was found just along the same cliff face slightly above the first rock shelter. This second shelter was referred to as west of Baron rock shelter 2 (WOBRs 2). In both of these rock shelters there was enough room to stand although the roof sloped sharply to the back wall. Evidence of recent use of these features was noted in the form of a rectangular bark stripped culturally modified tree near WOBRs 2. The remains of a cedar bark plank, possibly taken from the culturally modified tree, were found in WOBRs 2.

Subsurface testing was undertaken in both rock shelters. In WOBRs 2, auger testing revealed that large slabs of roof fall were common beneath a thin veneer of silty soil. For this reason, most of our subsurface testing was undertaken in the larger WOBRs 1. The bedrock outcrop beneath which this feature is located is quartz-diorite. A prominent vein of white quartzite occurs in the ceiling of the shelter at the northern end. In some areas, small quartz crystals were also noted in the overhanging ceiling. The shelter opens to the east.

A total of seven small shovel/trowel tests were undertaken in WOBRs 1. Sediments tended to be composed of mixed coarse sands, exfoliated quartz-diorite from the ceiling, and silts derived from organic accumulation in the rock shelter. Charcoal flecks were found to varying depths in different tests, the deepest was in St7 where charcoal was found to 60 cm db. The lowest sediments encountered were very hard packed orange stained sands with rounded pebbles, an iron stained (Bf horizon) parent

Figure 64. Map of archaeological site GdTr-4, Islet west of Baron Island.

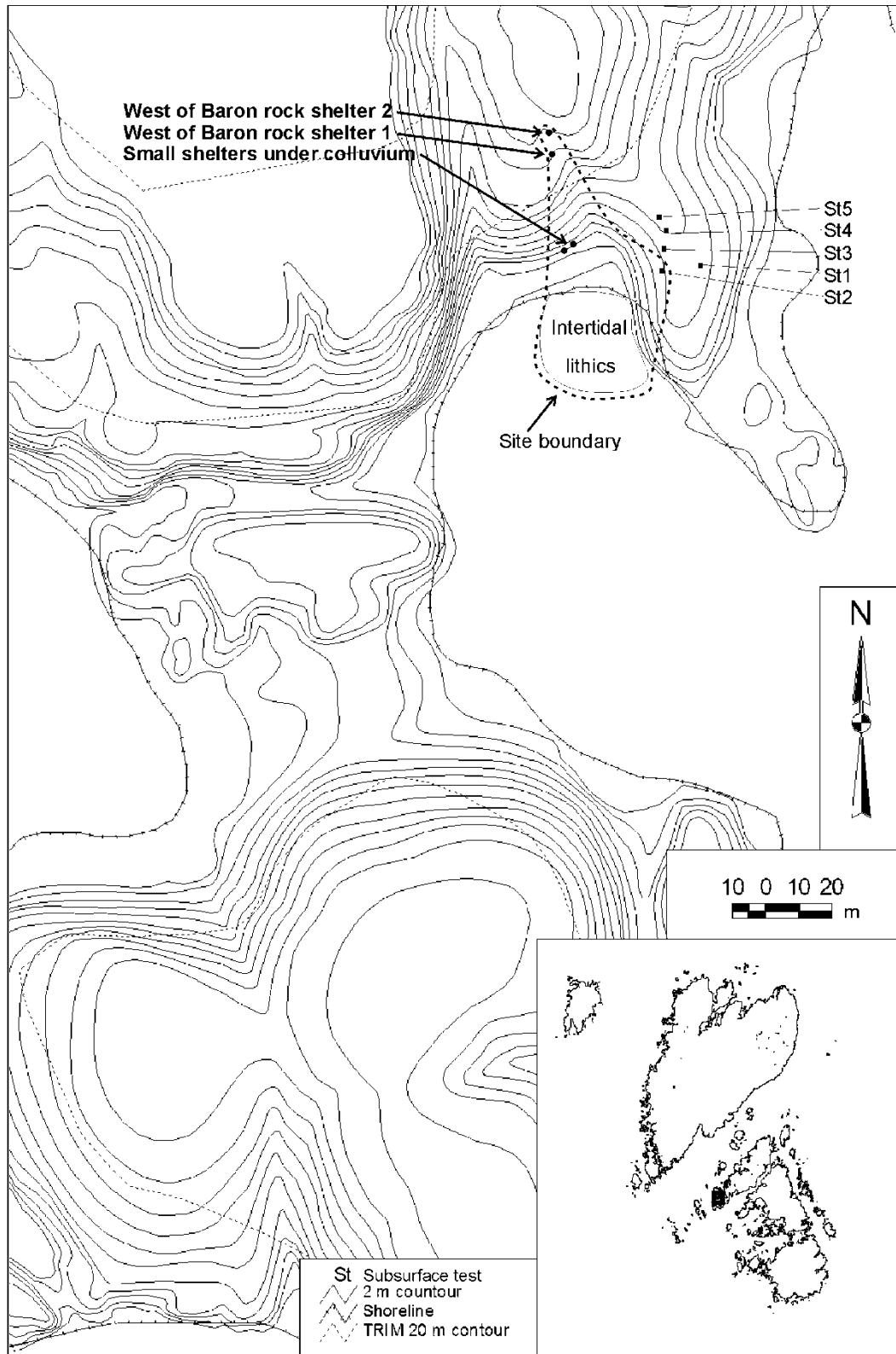
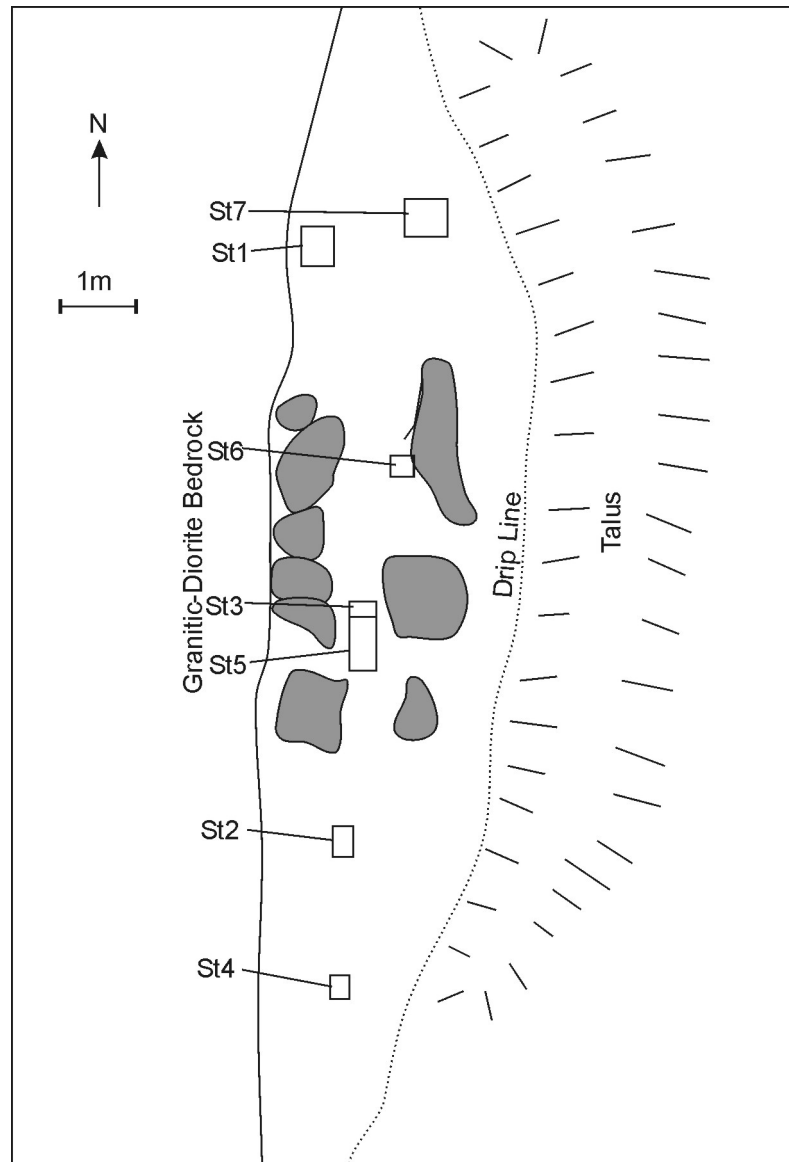


Figure 65. Map of subsurface tests (St) in west of Baron rock shelter 1, GdTr-4.



material (Figure 67). These lower sediments were not excavated past 10 cm below the transition to mineral soil (at the A to B soil horizon interface).

Many pieces of quartz crystal were found in the sediments, some with flake-like characteristics. This material can be accounted for without the intervention of human agency as the rock shelter ceiling has many quartz crystal inclusions. Screening also uncovered some basalt spall fragments and a basalt flake fragment with dorsal cortex between 60 and 50 cm dbs of ST 3 (Figure 67 and Figure 68). No basalt was noted in the rock shelter ceiling or cliff above and as this feature is very close to the top of small rise, it is unlikely that this material was derived from colluvial processes. Some seeds found between 60-50 cm dbs were selected and sent for radiocarbon analysis, but the sample was too small to analyze. For this reason, these deposits remain undated.

Figure 66. View of west of Baron rock shelter 1.



Figure 67. Profile of St3 in west of Baron rock shelter 1, GdTr-4.

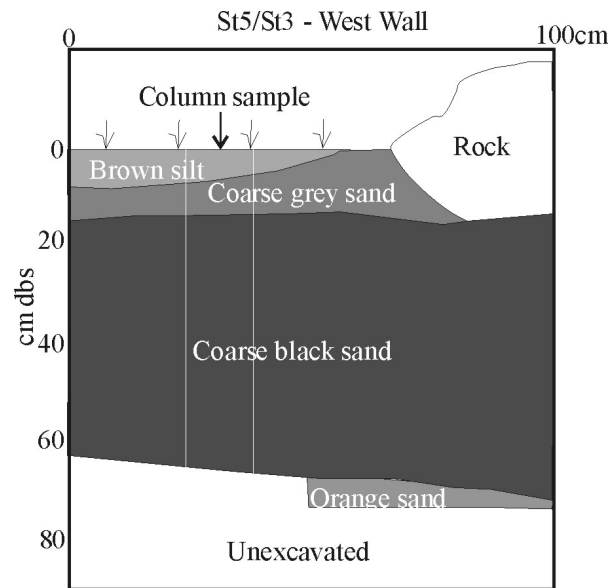
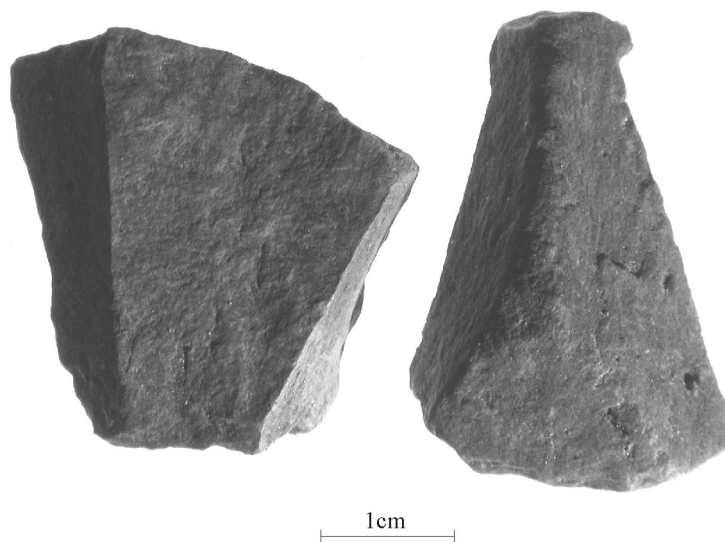


Figure 68. Lithics from St3, GdTr-4.



The combination of charcoal and two basalt flake fragments suggests evidence of human habitation in the sediments of this rock shelter. However, other than the charcoal flecks the density of cultural material was found to be very low. The presence of charcoal in these sediments does not necessarily imply human agency and may be the

result of nearby wild fires or lightning strikes. The saturated character of the sediments excavated suggests this shelter may have served as a damp refuge at times in the past.

A surface scatter of lithics was found on the beach that was used to access the rock shelter (Figure 61). All of these artifacts have resulted from the primary reduction of basalt cobbles (Table 13). In the cliffs faces above, no basalt outcrops could be located. Basalt outcrops do occur on the western side of Dunira and Baron Islands, as igneous dykes.

Table 13. Intertidal lithics collected at GdTr-4.

TYPE	MATERIAL	NUMBER
Flake, simple platform	Basalt	1
Flake, simple platform with dorsal cortex	Basalt	1
Flake, simple platform, possibly bipolar	Basalt	1
Flake, simple platform, alternating	Basalt	1
Flake, platform cortex	Basalt	3
Flake, faceted platform, dorsal cortex	Basalt	1
Spall	Basalt	1
Cobble core	Basalt	1
Circumferentially reduced cobble core, single platform	Chert	1
Circumferentially reduced cobble core, single platform	Basalt	1
Unifacial reduced cobble chopper	Basalt	5
Tabular core	Basalt	1
Pecked cobble anchor stone	Basalt	1
Total		19

In a sharp vertical bluff that lies on the east side of the intertidal zone, a cobble chopper was found wedged in a crevice. We undertook shovel testing on the flat area, directly above the location where this tool was found. Five subsurface shovel tests were undertaken on this terrace. Test elevations varied between 8 and 10 m a.s.l. as measured by altimeter. All tests had ~1 m deep soils with dark brown organic soil (LFH and Ah soil horizons) underlain by a gleyed soil. Tests bottomed out on bedrock.

In the second shovel test, located directly above the crevice caught cobble chopper, a dense concentration of charcoal was encountered between 70-60 cm dbs. Charcoal was not found in any of the other tests. We expanded this shovel test into a 1 x 1 m excavation unit. A circular, and hearth-like feature, was exposed between 67 and 65 cm dbs (Figure 69). A fire reddened central area to the hearth-like feature is surrounded by a halo of charcoal. The feature contrasts with the gleyed soil horizon in which the feature is set. No bone, lithics, or other cultural material was found in the excavation unit. A sample of this charcoal was sent for radiocarbon dating. This feature was dated to 2,530 +/-15 BP (UCIAMS 28010). While this hearth may be the remnant of past human land use, the lack of in situ lithics found in this test makes it difficult to correlate the intertidal lithics with these deposits. Charcoal and burnt soil can occur as a result of natural factors. At 70 cm dbs, this same unit bottomed out onto bedrock.

In summary, evidence of cultural occupation at GdTr-4 can be discerned from the intertidal lithics found on the protected beach. Test excavations undertaken in the rock shelter that lies 20 m above the barnacle line of this same beach revealed historic occupation in the form of a preserved plank, and a low density of lithics. The sediments from this rock shelter remain undated. Only sediments with an organic component were excavated; underlying Bf and C-horizons were not tested to any significant depth. On the terrace directly above the intertidal lithic scatter, a hearth-like feature was excavated. This feature, which was found to lie in a thick Ae soil horizon, dates to 2,530 +/-15 BP. No lithics or additional evidence suggesting human use were found in the subsurface tests that were undertaken on this terrace.

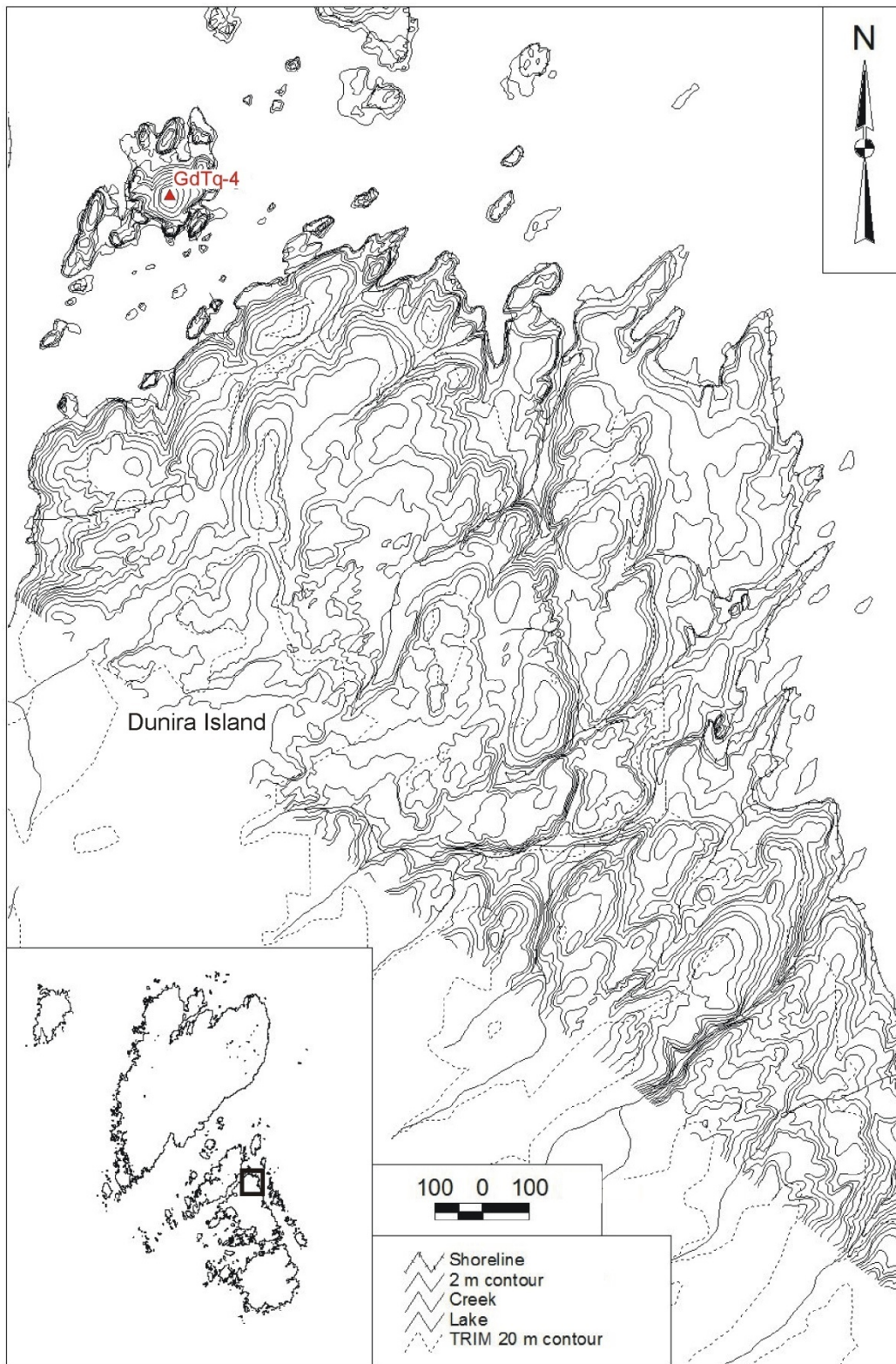
Figure 69. Hearth-like feature found in St2, west of Baron point.



Northeastern Dunira Island, Area F

The mapped area with 2 m contours on the northeastern side of Dunira Island was not actively surveyed for raised marine features and associated archaeological sites (Figure 70). The mapped area includes the north and eastern shoreline of Dunira Island and some islets that lie in the mouth to the channel that runs between Dunira and Baron Islands. Archaeological survey undertaken by Martindale and Brewster's survey crews found a large shell midden with 13 house depressions on one of the islands that lies in the mouth of the channel. This site is referred to as GcTq-4.

Figure 70. Location of GcTq-4 on islet northeast of Dunira Island, Area F.



GcTq-4

On a terrace, located between 4 and 8 m abl, are 11 distinct house platforms (Figure 71). Above these features is a steep rise to a terraced ridge that lies between 11 and 13 m abl. Two rectangular depressions are located on top of this ridge. ESP coring of the ridge top (13 m abl) revealed that 450 cm of sediment underlie the highest landform on this island, shell midden making up most of these deposits. Dating the bottom and top of midden deposits returned shell dates 6,830 \pm 70 BP (BETA 215178) and 5,290 \pm 40 BP (BETA 215179) respectively. Corrected for marine reservoir effect these dates are 6,230 and 4,690 BP. As expected, this feature is significant as the deposits are located above the early Holocene marine stillstand. Use of this part of the site for dumping shell appears to have ceased 4,690 BP, shortly after sea levels receded below 6 m abl, although more recent investigations suggest that the occupation spans to later times in the upper deposits of the midden (Ruggles 2007). Some of the house depressions on the lower terrace are also above this stillstand. It is not certain whether these house features date to this time of this stillstand or if they postdate the period of occupation on the higher feature.

Western Dunira Island, Area G

The western side of Dunira Island includes a long gravel beach and a long, narrow, rocky point that extends to the westernmost side of the islands (Figure 72). My survey crew conducted archaeological survey work in several locations in this area. Shell midden deposits situated on raised marine landforms were found in this mapped area at Far West Point.

Figure 71. Map of archaeological site GcTq-4, on islet between eastern Baron and Dunira Islands.

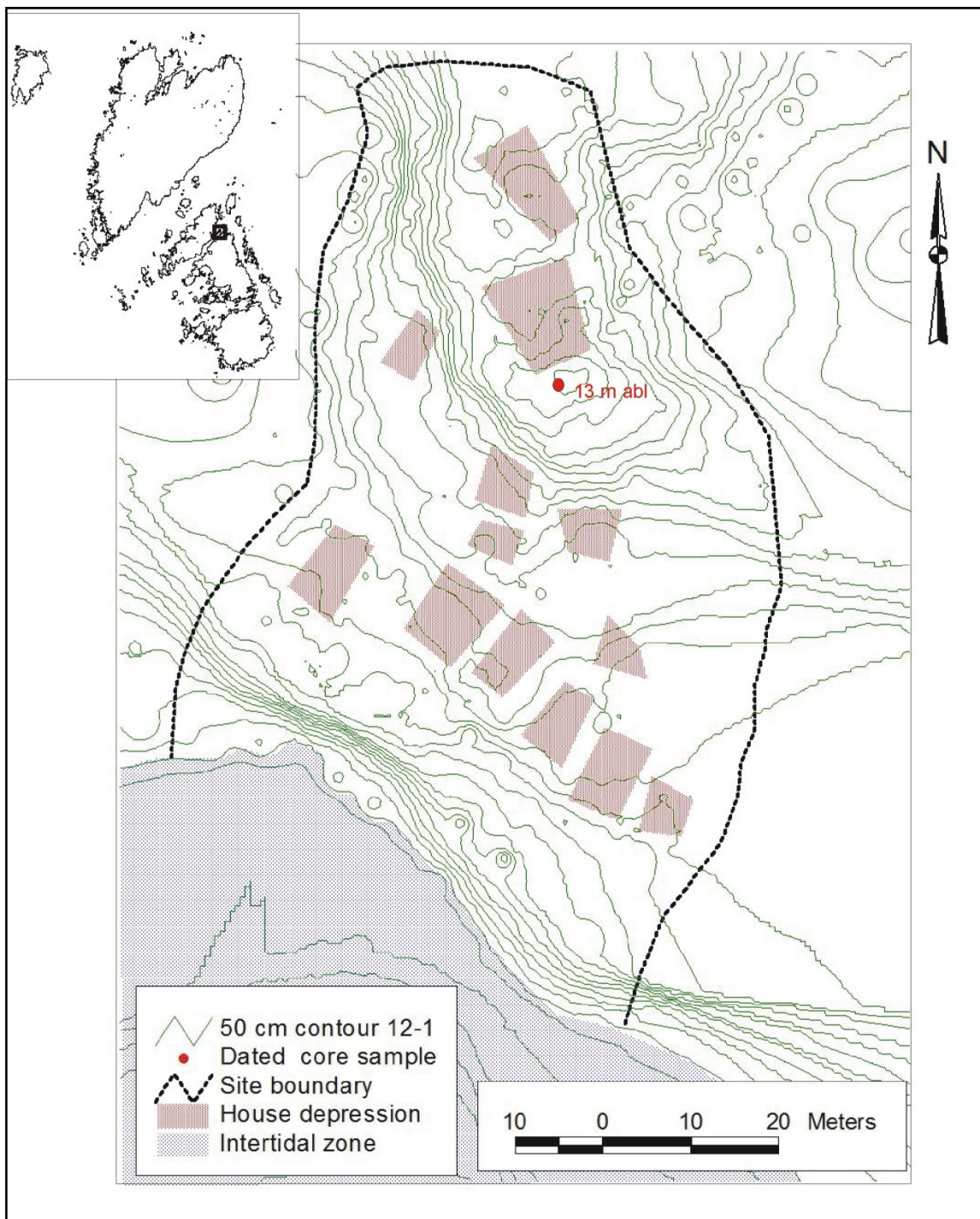
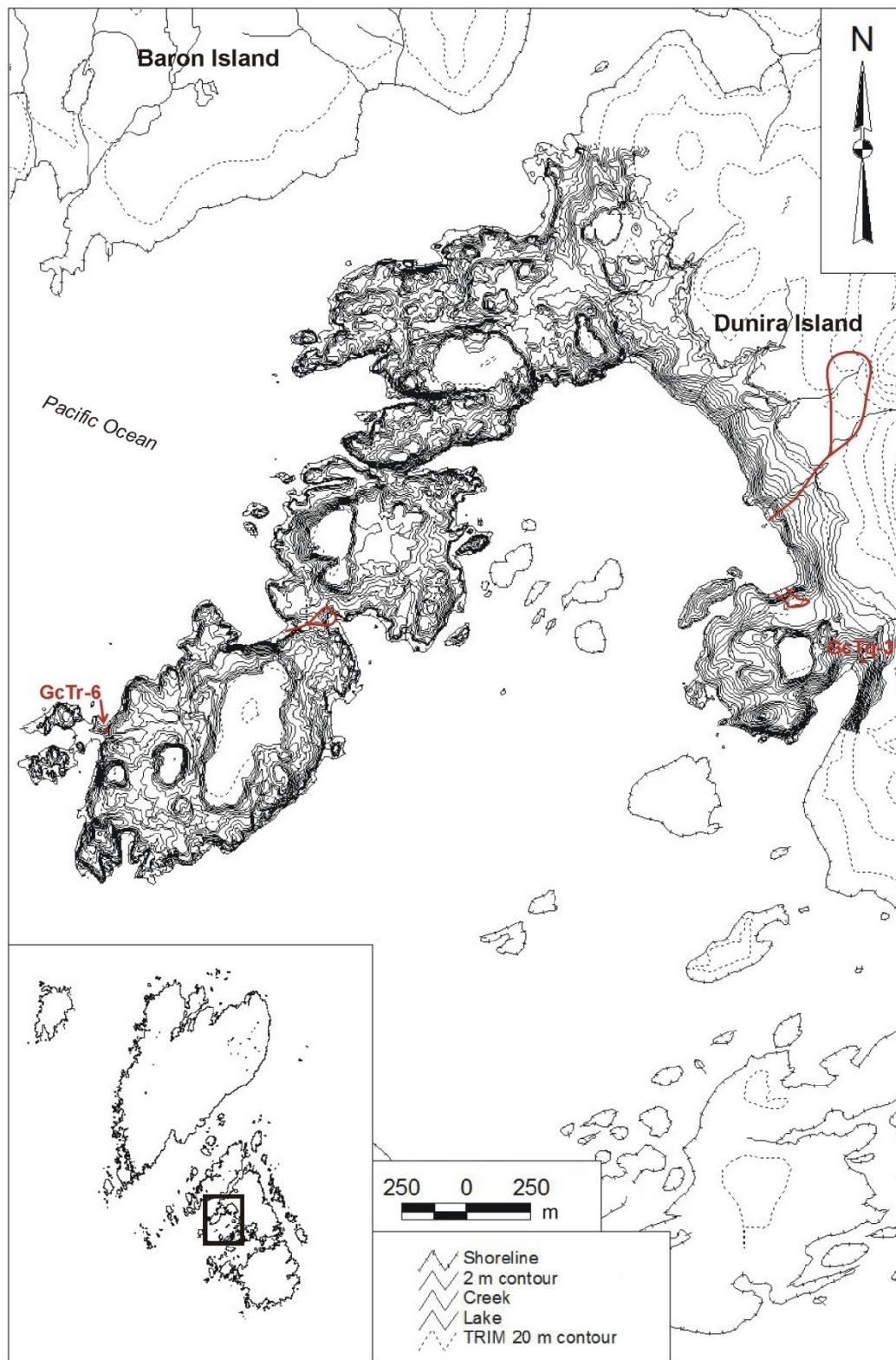


Figure 72. Archaeological survey on western Dundas Island, Area G.



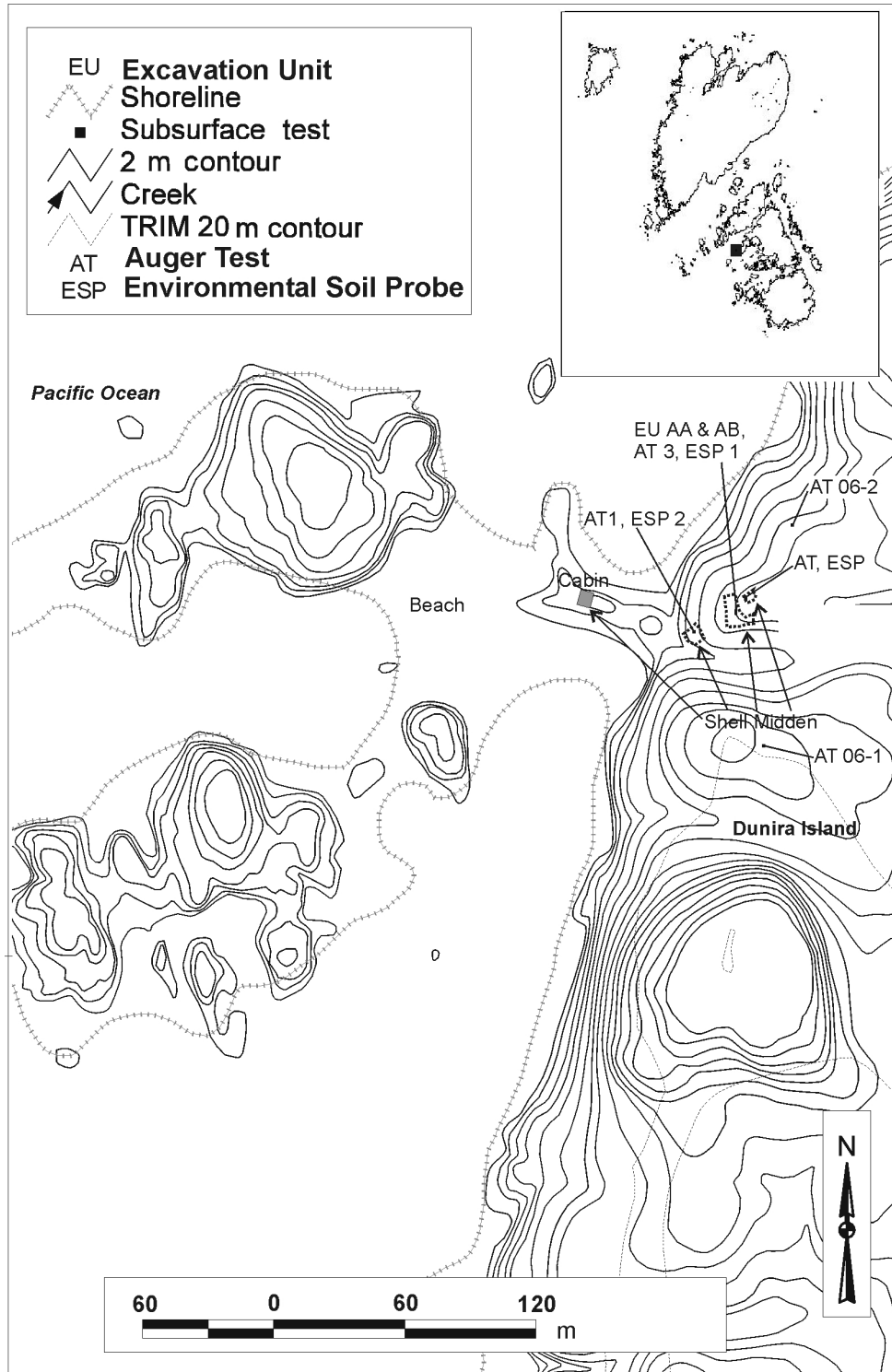
Far West Point (GcTr-6)

During archaeological prospection undertaken on Far West Point, on the west side of Dunira Island, archaeological remains were found to extend from the present shoreline to inland and elevated areas. The site is located on the Far West Point Indian Reserve at the western edge of Dunira Island (FWP). This site has four distinct occupation locations each separated by elevation differences (Figure 73). The latest occupation is a cabin and related midden deposit that sits on the present day shoreline (2 m abl). This is the cabin of Walter Green and family of Lax'Kw'alaams. This cabin is located at the top of a tombolo feature.

To the south and inland of the tombolo feature, a discrete shell midden deposit was found underlying forest soils at 5 m abl. Shell midden was found to a depth of 180 cm dbs (Figure 73). Bottom and top shell/wood pair dates were selected from an ESP core sample. The paired sample from the bottom returned a shell date of 4,200 \pm 15 BP (UCIAMS 21882) and a wood date to 3,645 \pm 25 BP (UCIAMS 21985). The difference between these dates is 555 years, 45 years less than the suggested correction of 600 year (Southon and Fedje 2003). Only a shell date was returned from the top deposits: 3,145 \pm 20 BP (UCIAMS 21883), calibrated for marine reservoir this date is 2,545 BP. These dates reveal that this discrete midden formed between 3,645 and 2,545 BP. Prior to 5,000 BP, this area would have been situated in the intertidal zone.

Two additional and discrete midden deposits were located on an 11 m abl terrace, directly upslope of the discrete 5 m abl midden and 30 m inland of the shoreline. The more northerly midden is located directly above an abrupt change in slope, likely a wave cut terrace. This midden has a distinct linear ridge with a right angle turn in it. It is

Figure 73. Map of archaeological site GcTr-6, Far West Point, Dunira Island.



approximately 3 m wide and 15 m long and is reminiscent of a house ridge with a corner, although the ridge does follow the natural slope break of the terrace (Figure 73). Fourteen metres to the northeast, a smaller, distinct midden heap was found. These two areas are separated by a slight depression that is rich in organic soils and charcoal and underlain by bedrock. This is possibly a structural depression.

On this 11 m terrace auger and ESP core samples were taken from front midden deposit and revealed 2.75 m of sediments (10.99 m abl – 8.24 m abl), with shell underlying forest soils below 80 cm to a depth of 250 cm. I selected a shell/charcoal pair for dating the basal midden deposits. This paired sample was dated to 7,510 \pm 20 BP (UCIAMS 31730) on mussel shell and 6,925 \pm 50 BP on charcoal, a difference of 585 years, very close to the suggested 600 year correction (Southon and Fedje 2003). These dates reveal that the midden accumulation found below the 11 m abl terrace had been occupied during the time when sea levels were above 6 m abl.

From the back midden deposits, auger and ESP core sampling revealed midden deposits to 153 cm dbs, with a distinct underlying black silt which grades into brown sand. No radiocarbon samples collected from this location have been analyzed.

An excavation unit was placed into the deposits dating to 6,925 BP. The results of this excavation are presented in a separate section on page 243.

Survey Northwest of Far West Point

To the northeast of Far West Point, we surveyed across an isthmus-like feature. The forest in the area was found to have burned in recent years (Figure 72). Completely charred logs, tree remains, and fire-scarred trees were noted. This evidence demonstrates

that despite the very wet hypermaritime conditions on the Dundas Islands they can be dry enough for significant forest fires to develop. Such events can contribute to soil charcoal.

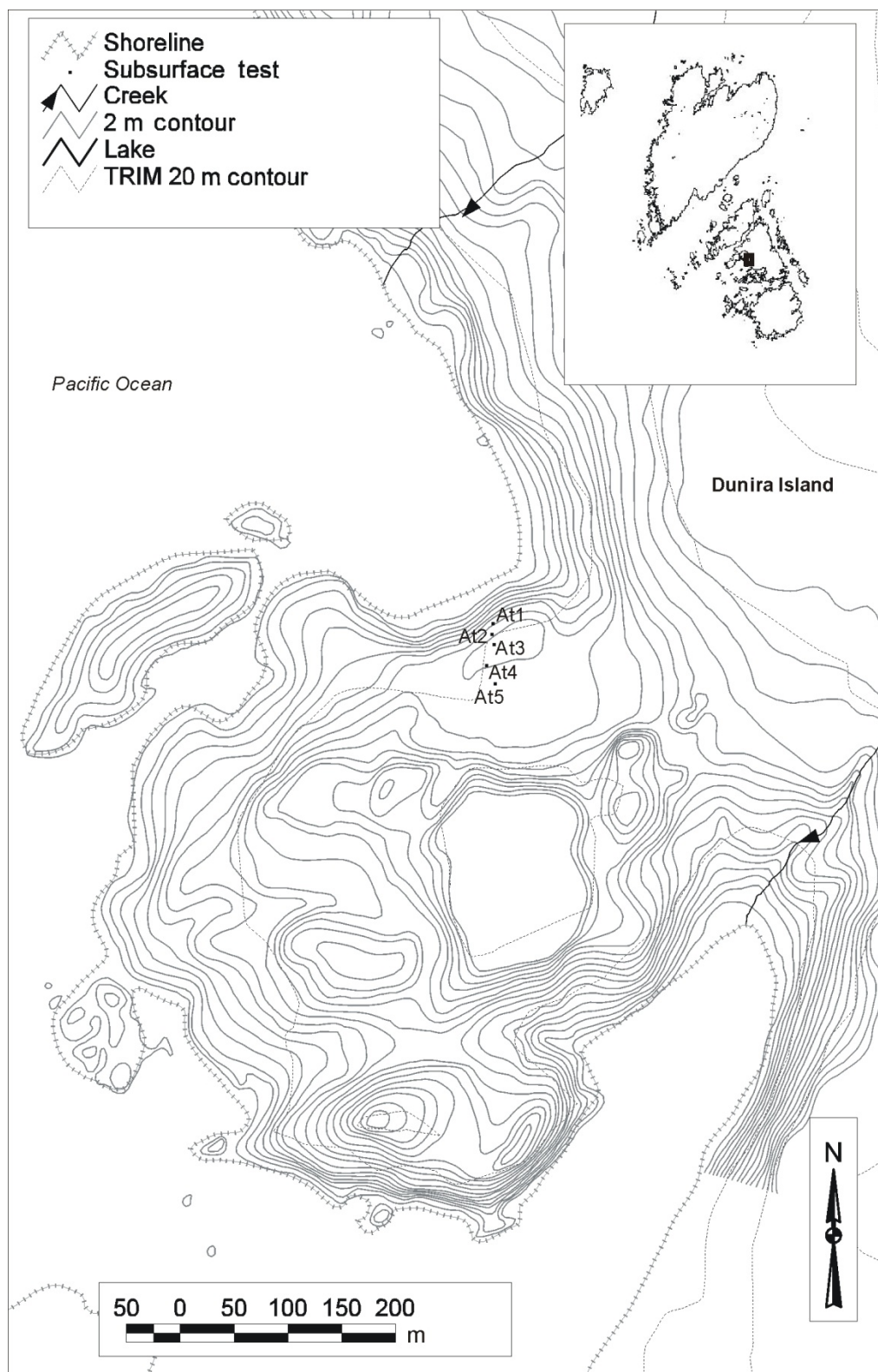
Survey of Beach on West Side of Dunira Island

To the southeast of the peninsula feature, that characterizes the northwest end of Dunira Island, lies a linear gravel beach with a steep rise to 14 m abl (Figure 72). At 14 m abl a terrace-like feature could be discerned from the 2 m contour map. My survey crew undertook a traverse into this area to inspect this terrace. A creek bed was used to hike up to the flat terrace. Here dense blanket bog was encountered. A steep area above the bog was traversed and several bluffs in the area were examined for rock shelters. No rock shelters were found and no subsurface testing was undertaken in the saturated deposits that topped this terrace.

Southwest Dunira Terrace

At the south end of this linear beach feature is a small north-facing bay (Figure 72). A prominent terrace was noted on the 2 m contour maps at 16 m abl. My survey crew targeted this area for subsurface testing using probes and augers (Figure 74). A peat bog on this terrace is drained by a small stream (not indicated on the map). At the lower and front end of the terrace, between 11 and 14 m abl (as measured by altimeter), an area with better drainage was found and auger and probe testing was undertaken. A total of five auger tests were undertaken. Soils were found to be black humus over a leached Ae Horizon. Beneath the Ae horizon, orange stained sands were found suggesting underlying beach deposits. Some charcoal was found in auger tests 3 and 4. Probe testing revealed charcoal concentrations along the edge of the terrace. No definitive evidence of cultural occupation was found at this location using auger and probe tests.

Figure 74. Subsurface tests undertaken on terrace feature on south side of Dundas Island.

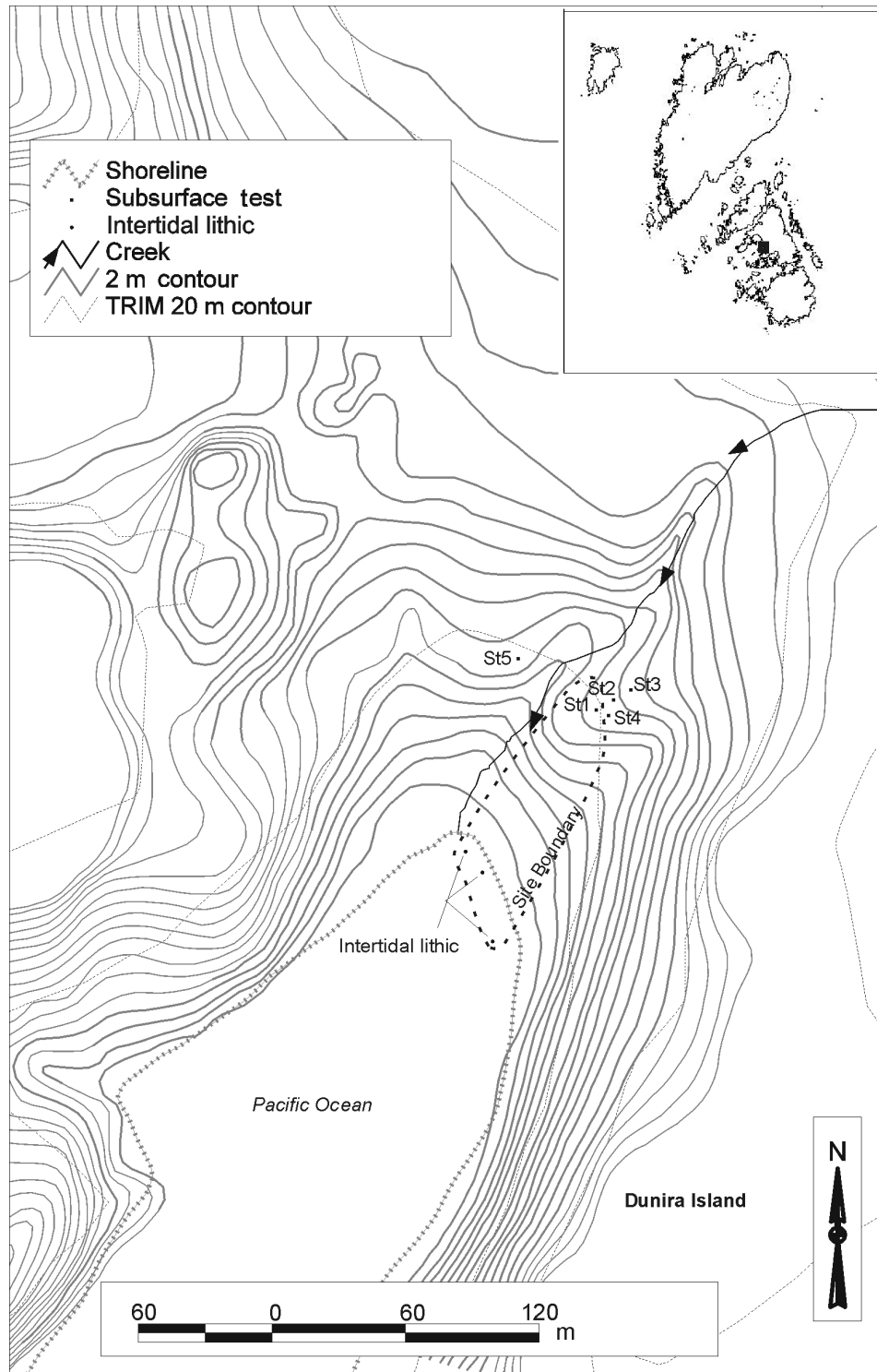


GcTq-3

Directly to the south of the area just described, and tucked into a southwesterly facing bay, is a mapped creek outlet (Figure 75). Our survey in this area revealed the presence of a pronounced terrace the top of which lies at 15 m ahl, as measured by altimeter. This terrace rises fairly abruptly just above the vegetation line. On the southeast side of the creek this area appeared to be better drained and was selected for auger and shovel testing. A total of four shovel tests and one auger test was undertaken on the southeast side of the creek. One shovel test was excavated on the swamplier northwest side of the terrace. These tests revealed a blackish brown Ah soil horizon with a pronounced silty Ae horizon. Sandy Bf and C horizons were found beneath. Charcoal flecks were encountered in the lower Ah and Ae horizon sediments in three of the tests undertaken.

From the first shovel test undertaken (St1), the mid-section of a quartzite microblade was found while water screening. This object was found in the Bf sands. Although missing a platform, the object has a characteristic trapezoidal cross-section and two parallel dorsal flake scars. No other archaeological remains were found during any of the subsurface tests on this terrace. Some intertidal lithics were found on the beach in front of the site, including three cobble choppers. Due to the steep rise directly above the vegetation line, it is possible that these lithics have washed from the terrace above. No radiocarbon dates were acquired on samples collected from this site. This site is recorded as GcTq-3.

Figure 75. Map of GcTq-3, southwestern Dunira Island.



Northwest Melville Island, Area H

My field crew examined two distinct areas for archaeological remains on the north side of Melville Island (Figure 76). These areas, from west to east include an isthmus and a raised alluvial fan that has been intersected by a mapped creek.

GcTq-2

During archaeological reconnaissance, a sedimentary exposure recorded during palaeo-environmental survey of this area was revisited (Figure 77 and Figure 78). In this exposure, raised intertidal deposits were identified, and upon returning, a basalt spall tool was found within the clast supported cobble and pebble stratum (see “Chapter VI - Dundas Island Archipelago Late Pleistocene and Holocene Sea Level History”). These gravels are in a Bf to C soil horizon transition zone and are likely the remnant of sedimentary materials deposited in the upper intertidal zone. Based on the elevation of this tool in the upper intertidal zone, it is estimated that it would have been deposited in these sediments after 9,500 BP and before 5,500 BP. Archaeological deposits in this area were recorded as GcTq-2.

The isthmus above this exposure rises to 16 m abl. Several areas along the ridge of the isthmus are flat and fairly well-drained (Figure 77). Subsurface testing was targeted in areas between 10 m abl and 18 m abl. We undertook auger testing along the length of the isthmus. Soils were found to have a relatively thick black silty Ah horizon with a thick and underlying gleyed soil. Beneath the organic soil encountered in these tests, a thin and cemented Bf horizon was encountered. This cemented layer formed over consolidated sandy gravel, most likely relict beach deposits similar to those identified in the exposure. Charcoal concentrations were noted in only a few of the auger tests.

Figure 76. Archaeological survey on northern Melville Island, Area H.

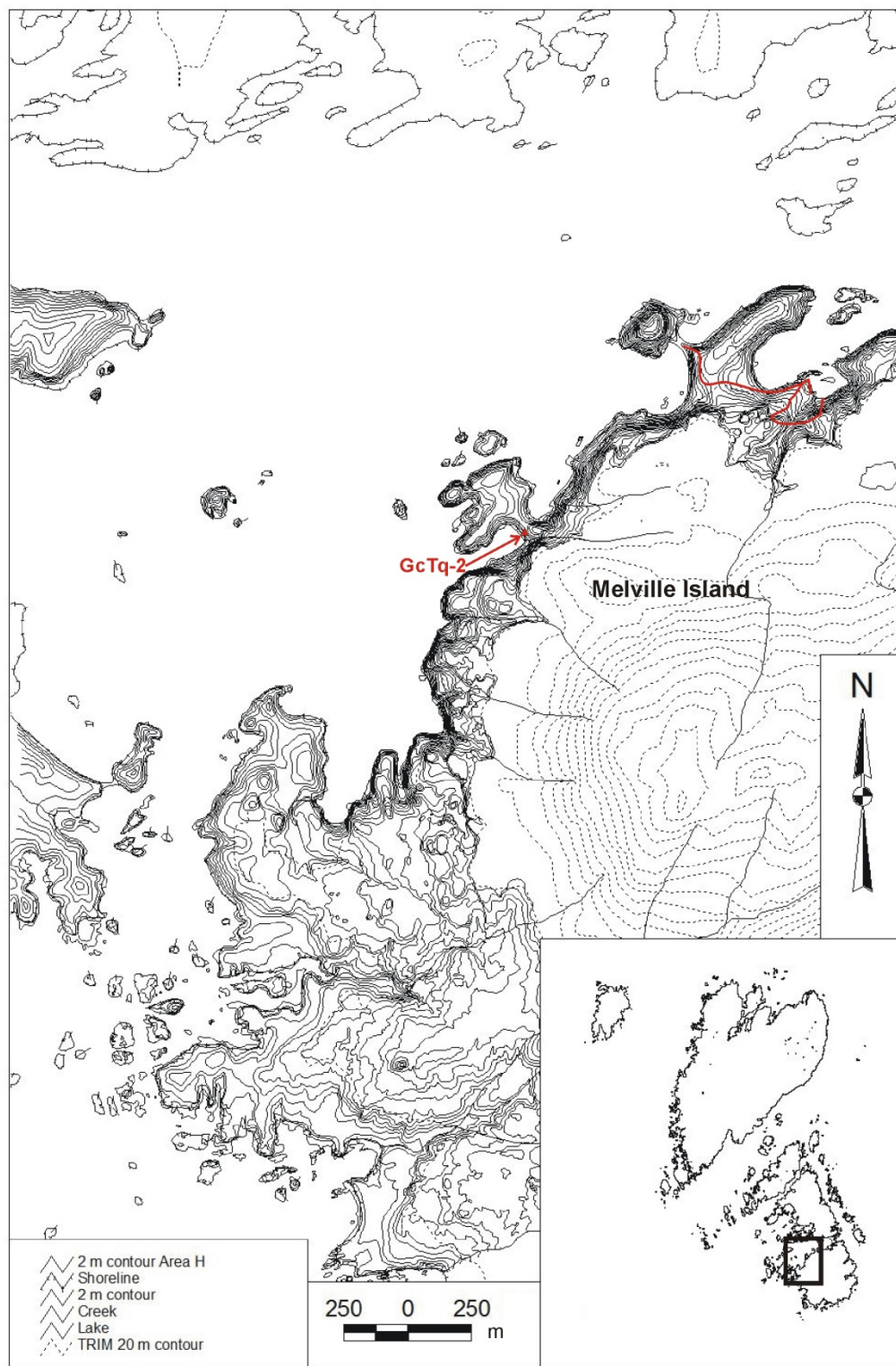


Figure 77. Map of archaeological site GcTq-2, north Melville isthmus.

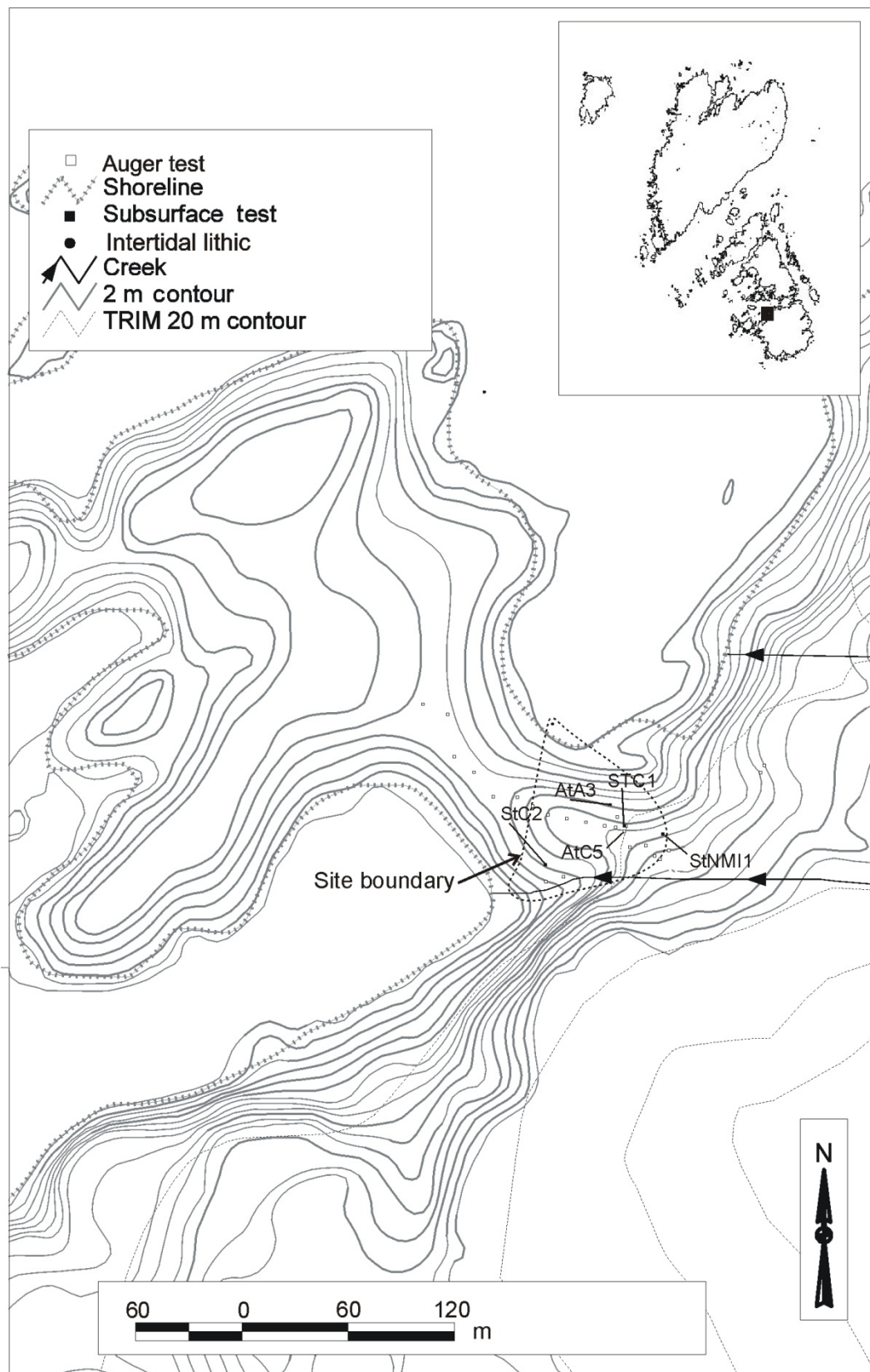
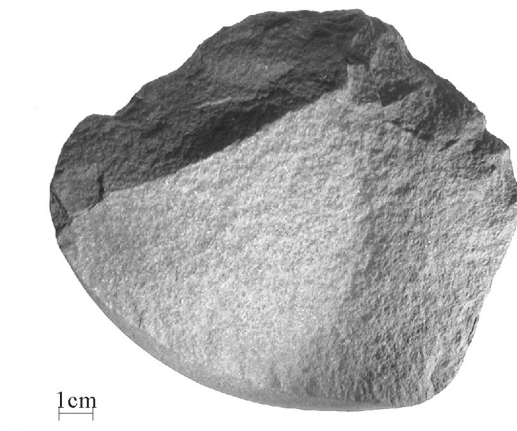


Figure 78. Spall Tool found in Relict Intertidal Sediments (GcTq-2).



Shovel tests were placed in locations where charcoal was found. Both shovel (St) and auger (At) tests revealed some evidence of human occupation. One flake was found in each of the following tests AtA3 (12 m abl), AtC5 (14 m abl), StMNI1 (16 m abl), and StC1 (14 m abl). In most cases these lithics turned up in Bf or C horizon deposits, implying they were deposited when this feature was active in the intertidal zoned. We expanded StC1 into a 1 x 1 m excavation unit (Figure 79). This unit was excavated to 1 m below the surface at 14 m abl through Bf and C horizon gravels into C horizon sand (Figure 79). No further evidence of cultural remains was encountered in this excavation.

One unifacial cobble chopper, a circumferentially reduced cobble core, and a charcoal concentration were encountered in the Ae horizon of unit StC2 lying at 12 m abl (Figure 80 and Figure 81). This 50 x 50 cm unit was excavated where an abundant charcoal concentration was found in an auger test. Although flaked using percussion, the outer rinds of these lithics are extremely weathered. This may be the result of the highly acidic nature of the gleyed soils excavated. A radiocarbon sample was selected from charcoal that was found in direct association with one of these lithics. This sample produced a date of 6390 \pm 20 (UCIAMS 28009). This date reveals that this terrace was occupied during the early Holocene stillstand. Archaeological deposits in this unit may represent a contemporaneous occupation to that represented by the spall tool located in the raised intertidal deposits of the north Melville exposure.

During subsurface testing on this terrace, several flake-like objects were found. However, these were found to be very delicate and fell to pieces when handled. It is most

Figure 79. Profile of StC1, 1x 1 m excavation unit on North Melville Isthmus, 14 m abl.

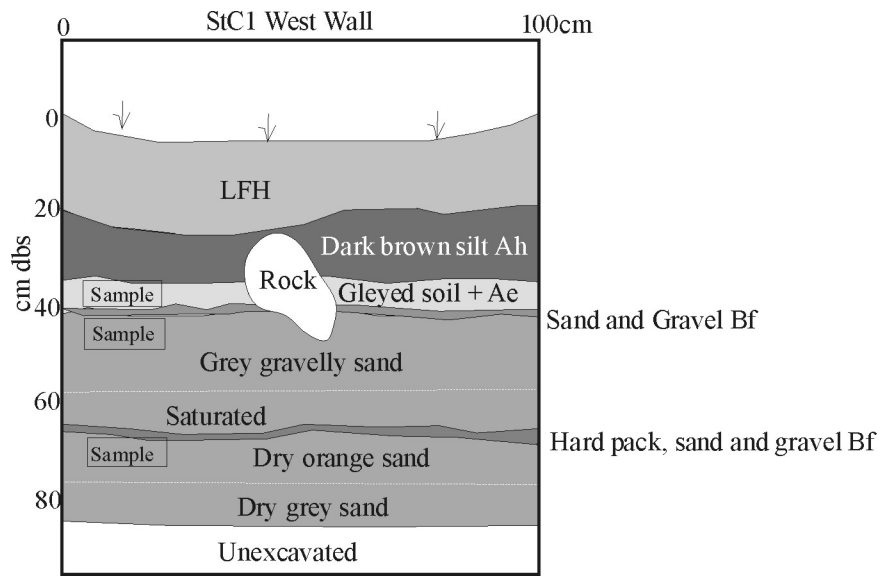


Figure 80. Profile of StC2, 50 x 50 m excavation unit on North Melville Isthmus, 12 m abl.

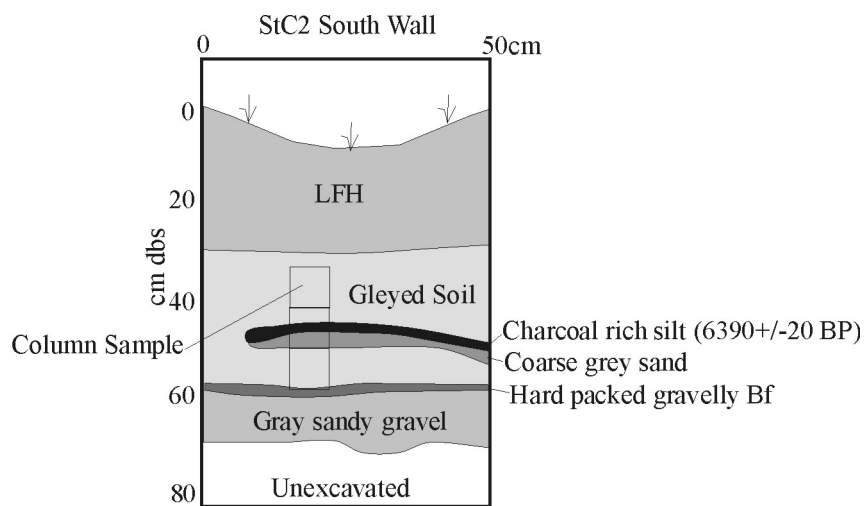


Figure 81. Cobble tool and circumferentially reduced cobble core found in association with charcoal rich silts of StC2.



1cm

likely that they are the remains of sedimentary rocks or schists unsuitable for lithic production. These types of rock are common on the Dundas Islands (Hutchison 1982). In light of the extremely weathered condition of much of the rock found in the soil of this area it is possible that some of these may have been heavily weathered lithics manufactured from a metamorphosed sedimentary rock such as argillite that is now structurally weak and exfoliating.

Some argillite-like tablets were found in the current intertidal zone below this terrace. Experimental hard hammer flaking of this material revealed that flakes could be easily removed and were strong enough to hold an edge. The ventral surface of these flakes is unique as combinations of conchoidal fracturing combined with fracturing along naturally occurring bedding planes gives an uncommon scarred look. A very similar material was used to produce the flake found in the raised beach sands excavated at 14 m abl in StC2. All other flakes appear to be rough-grained basalt, similar in appearance and texture to the spall tool that was recovered from the 7 m abl exposure on the south side of the isthmus, and the lithics excavated at Far West Point.

Results from GcTq-2 reveal that cultural deposits are rare, but do occur in the upper raised beach deposits, above 14 m abl, of the isthmus feature. No radiocarbon dates have been submitted to date the beach sands at this elevation, but from the sea level curve produced for the area it is possible that these flakes are the remnants of cultural activity dating between 12,000 and 10,000 BP. All of these flakes have platforms and distinct bulbs of percussion. However, as these are primary stage flakes, without additional evidence of cultural material, this site does not stand up to the criteria previously outlined for identifying pre 10,500 BP sites (Dixon 1999) as such objects

could conceivably be created by natural agents. Despite the considerable effort and energy that was put into testing this landform, pre-6,390 BP occupation is hinted at but remains inconclusive. Non-shell midden occupation of a raised beach feature dating to 6,390 BP was identified with the lithics and charcoal in StC2.

North Melville Creek

Lying along the shoreline to the east of the North Melville Isthmus is a small mapped creek that runs into a small bay (Figure 82). Foot surveys found a terrace rising from 6 to 14 m abl. This terrace is not clearly discernible from the 2 m contour maps. The terrace rises gently to 17 m abl before a set of bluffs are encountered. Through auger testing it was found that soils in this area included a very saturated black Ah under which soils are gleyed. Under the organic soils, a thin hard packed sandy gravel Bf horizon was found. Some exposures located above the creek revealed that most of this landform is composed of sands and gravels.

In At3 a concentration of charcoal was found in the basal organic gleyed soils (Figure 83). We excavated an 80 x 60 cm unit to test the deposits further. Wood was found to be well preserved as a result of the anaerobic condition of the soil. A dense charcoal layer was encountered at 30 cm dbs contrasting with the light brown colour of the gleyed soil. Directly underlying this clay, a thin veneer (0.5 cm) of fine grey sand was discovered (Figure 82). No definite archaeological remains were located during the course of this testing although one piece of preserved wood was collected as it appeared to have been sharpened to a point. A charcoal sample was selected for radiocarbon analysis for the concentration. A date of 3,880 \pm 20 BP (UCIAMS 28011) was returned.

Figure 82. Subsurface testing locations near creek on the northern side of Melville Island.

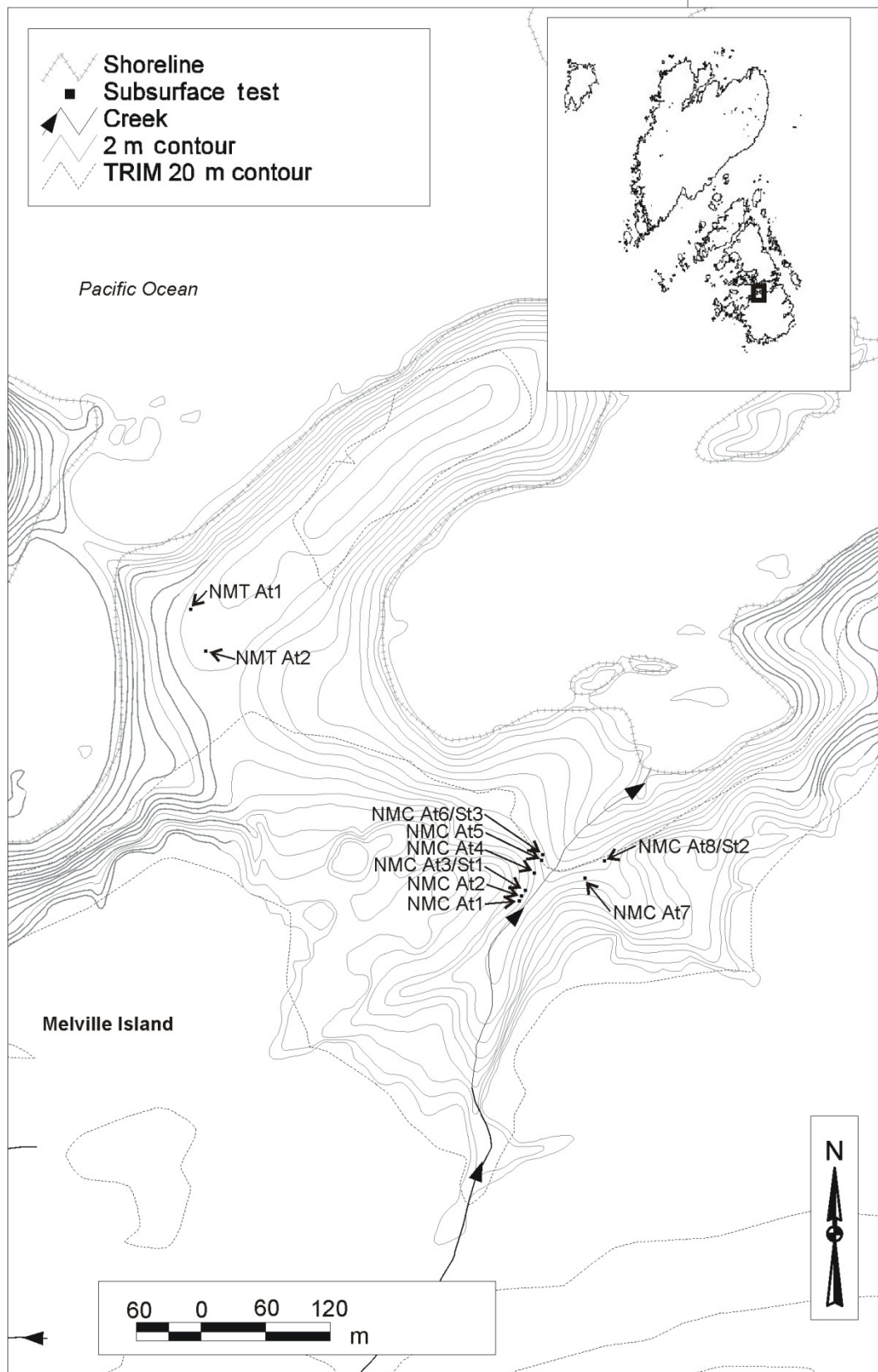


Figure 83. Profile of subsurface test 1, north Melville Creek.



Due to the lack of positively identified archaeological remains from this test and the late date, it is felt that this deposit may be the result of a natural burn in the area 3,880 BP.

Other Areas

My survey crew undertook some archaeological prospection outside of those areas mapped with 2 m contours. Rock shelter surveys were undertaken on the outer islands to the west of Baron Island, the Connel Islands, and in Edith Harbour on southeastern Dundas Island. Many small rock shelter locations were found during the course of these traverses but were either found to be below 6 m abl or were too small for prolonged human occupation.

GcTr-7

On the Connel Islands, an archaeological site was found well above 6 m abl on a dune feature (Figure 84). This site is referred to as GcTr-7. Erosion of this dune revealed that it has accumulated between 6 m abl and 17 m abl above a tombolo feature that connects two of the outermost Connel Islands. For the most part these dune sands are covered by herbaceous vegetation (Figure 85). An exposure at the apex of this dune feature, revealed a thin layer of shell midden, charcoal, and bone (Figure 86).

An ESP core was taken at the apex of the dune feature. The same midden deposits exposed in the profile were picked up in the ESP core at 95 cm dbs. A shell/wood pair radiocarbon sample was selected from the ESP core tube. A shell date of 1395 \pm 15 BP and a charcoal date of 640 \pm 60 BP were returned. The discrepancy between these dates is 755 years, slightly older than that cited as the marine reservoir correction for this time period (600 years), but within the 100-200 year window of variation around this estimate (Southon and Fedje 2003). In total, a 3.68 m ESP core of sediments was taken at the apex of the dune, which lies at 17 m abl. Almost the entire core is dominated by medium and fine-grained biogenic sand with an occasional thin 1 cm band of organic silty sand in the top 1 m of deposits. Beneath these sands (356 cm dbs), 10 cm of brown clayey silt were encountered before clasts stopped the coring device. A seed found at the transition between the dune sediments and this underlying organic silt was selected and sent for radiocarbon analysis. However, after preparation the sample was too small to run a reliable radiocarbon date. Some rectangular shaped depressions found behind the crest of the dune may represent structural remains.

Figure 84. Map of archaeological site GcTr-7, Connel Island Dune.

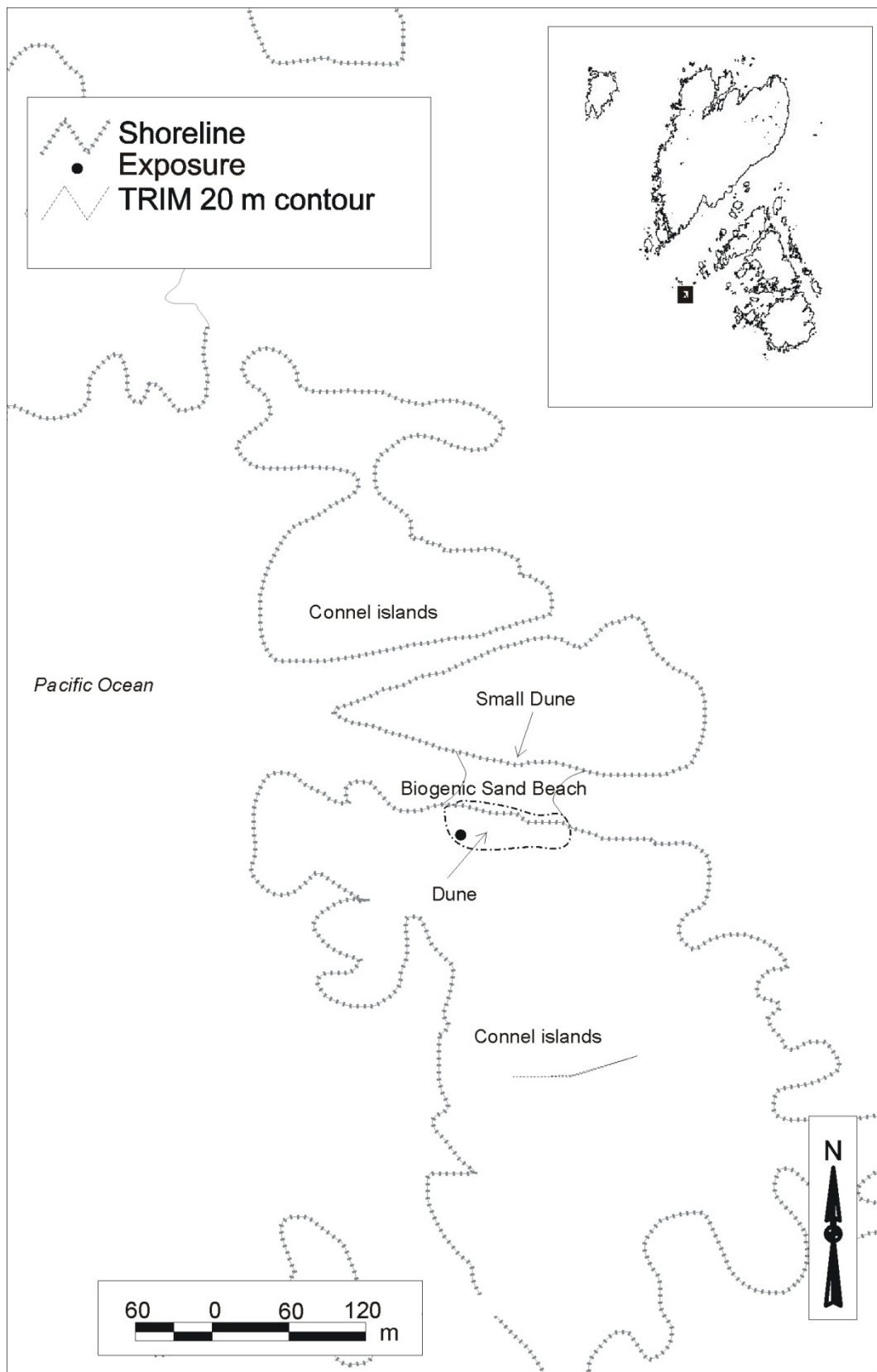


Figure 85. General view of GcTr-7.



Figure 86. Exposure with hearth feature at top of GcTr-7.



The presence of these deposits, including a large hearth feature at the apex of this dune suggests the possibility that this feature was some type of refuge being elevated, steep sided, and easily defended. This is one of the most westerly points of the southern Dundas Group and this site may also have served as a staging place for crossing Dixon Entrance to Graham Island (Moss 2007). The Connel Island dune demonstrates that features well above the present day shoreline were targeted and used in the late Holocene. The lack of woody vegetation on this dune suggests that it may still be an active geomorphic feature.

Excavations at GcTr-6, Far West Point

GcTr-6 was found during survey on the west side of Dunira Island (see page 222). Midden deposits located on the upper terrace at Far West Point, and we tested these using a 2 x 1 m excavation unit (Figure 87). This unit was stepped to a 1 x 1 m excavation unit to reach the bottom of the 2.75 m of deposits. All excavated cultural-bearing strata were water screened through 3 mm mesh. Artifacts and faunal material were recovered and collected. Three 10 x 10 x 5 cm column samples were taken from deposits on the eastern wall of the unit (Figure 89).

Non-shell radiocarbon samples were selected from different elevations within one column. The shell midden deposition was found to date between 6,940 BP (UCIAMS 30930) (250-255 cm dbd) and 6,185 BP (UCIAMS 30932) (60-65 cm dbd), and underlying cultural material-bearing and charcoal rich, greasy, black silt was dated between 9,690 BP (UCIAMS 28008) (265-270 cm dbd) and 6,940 BP (UCIAMS 30930) (250-255 cm dbd). All of the dates are in stratigraphic sequence with the exception of one, a charcoal sample from the same 10 x 10 x 5 cm column sample, which was selected

to verify the 9,960 BP date. This sample returned a date of 6,800 \pm 60 BP (TO 13292). This is the only sample that was analyzed at a different lab. The reasons for this out-of-sequence date are not known although there may be some admixture of deposits or a possible unconformity (buried erosional surface that separates two strata of different ages).

The sediments directly surrounding the charcoal sample that yielded the 9,690 BP date were examined with an optical microscope; fragments of sea urchin, mussel, clam, sea mammal bone, and fish remains were identified. A sample of sea mammal bone was collected from these sediments and sent for radiocarbon dating. However, after initial sample preparation, not enough material was found to be dateable.

Figure 87. Photo of east wall profile of excavation unit at GcTr-6.



Figure 88. Location of excavation units, GcTr-6.

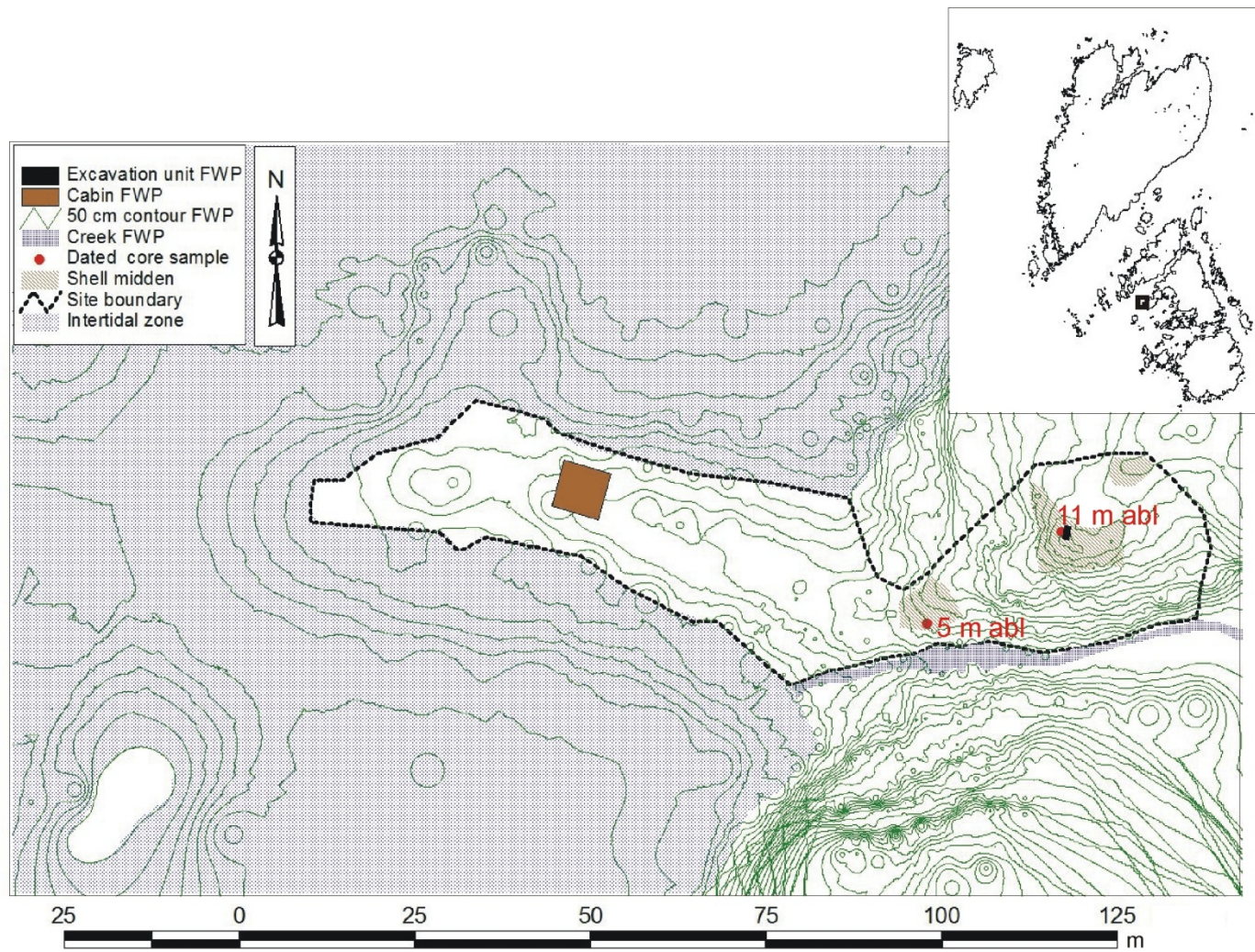
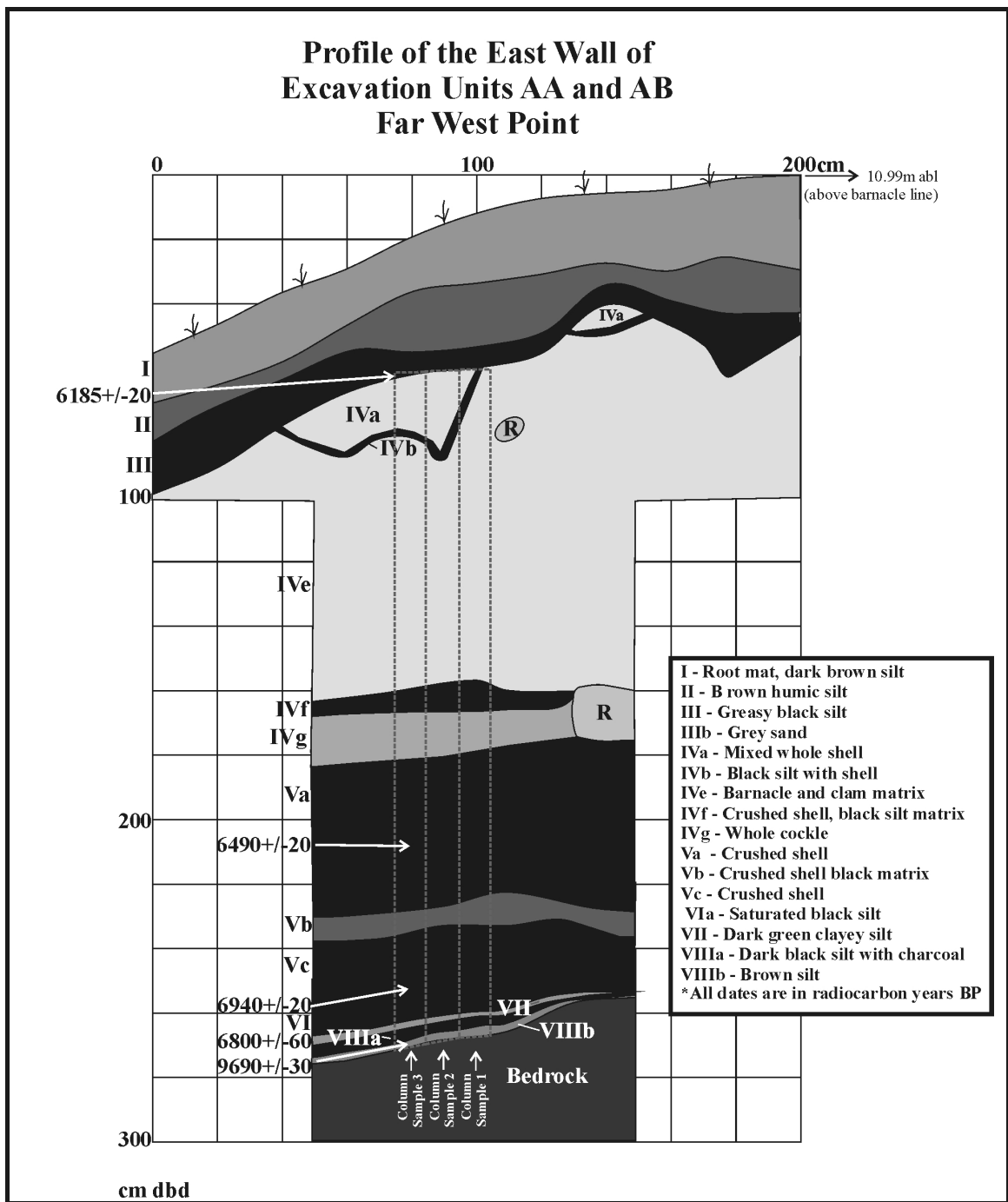


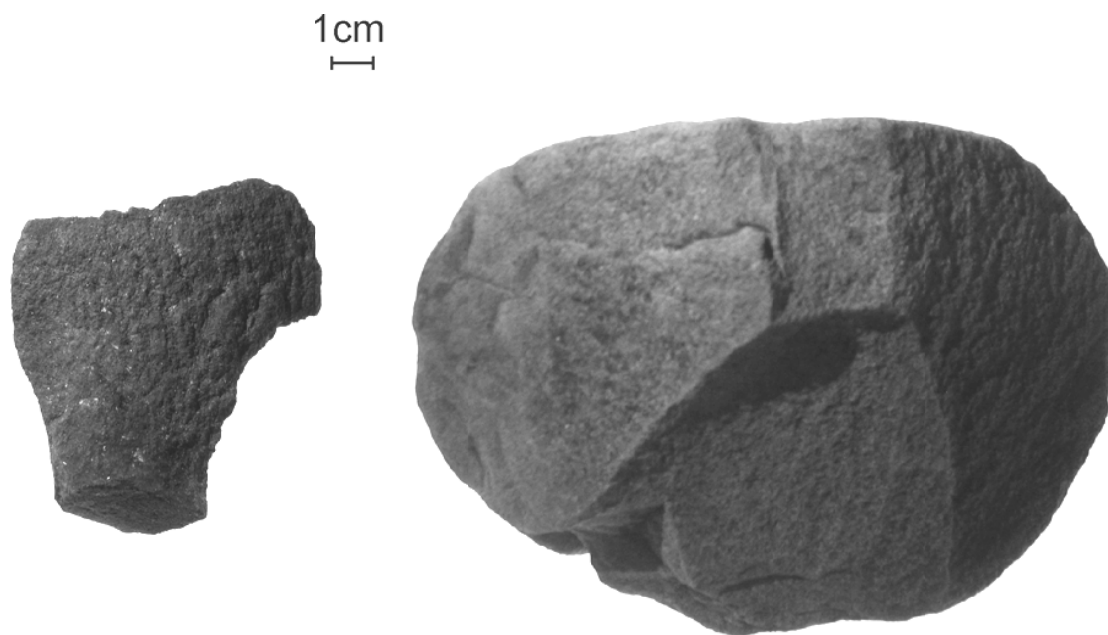
Figure 89. Profile of east wall from excavation units AA and AB, GcTr-6.



Bone and stone artifacts occur in low abundance throughout the deposits. Lithics recovered include one cobble core, a spall tool, and a flake (Figure 90). All of these are

made out of coarse grained basalt. Basalt cobbles are occasionally found in the current intertidal zone on the southwest side of Dunira Island.

Figure 90. A spall and a cobble core from shell midden deposits, GcTr-6.

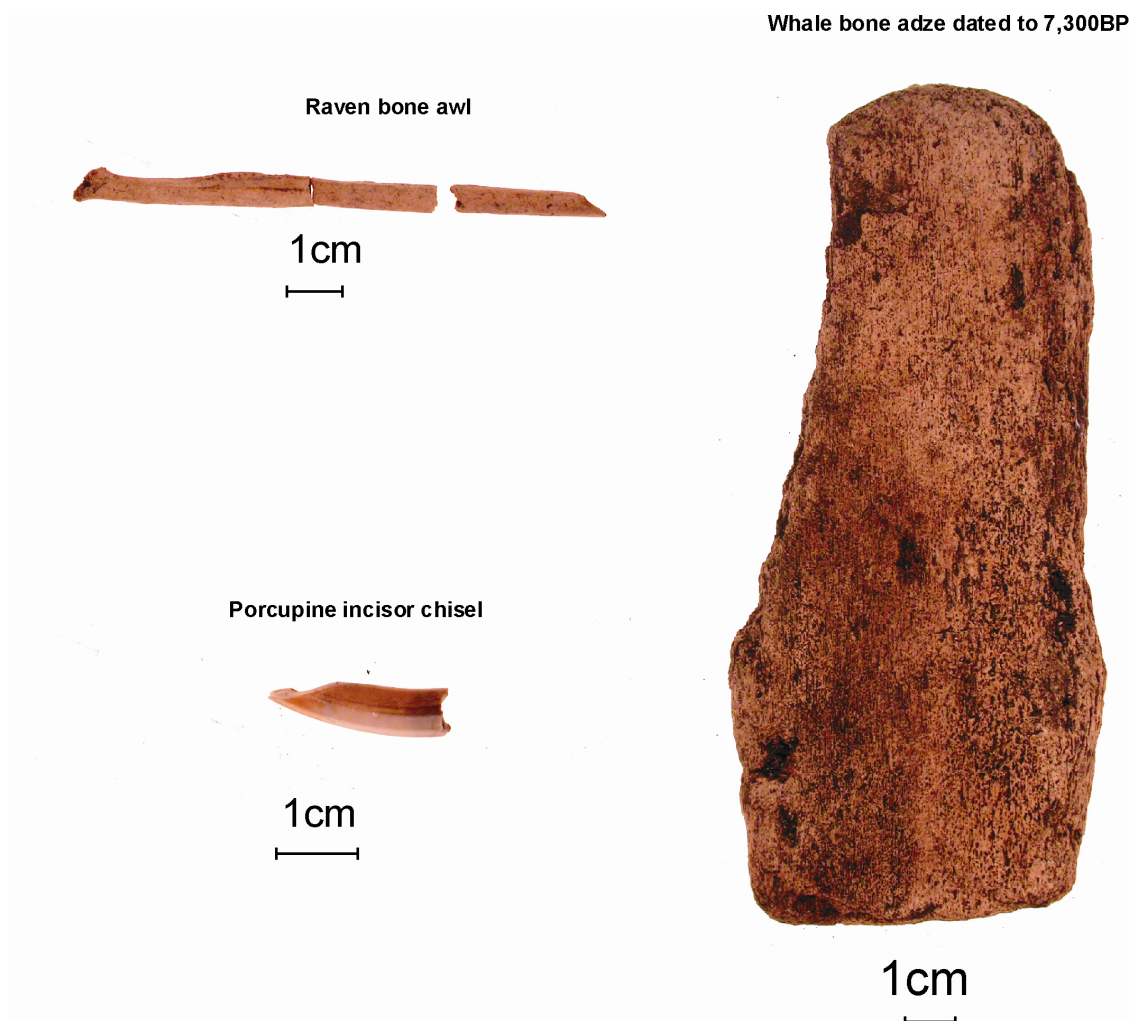


Among the bone objects found are: a raven bone awl, bird bone tube beads from the shell midden component, and a whalebone adze that has been directly dated to 7,300 \pm 30BP (265-255 cm db) from the black silt (Figure 91). As whales are migratory, the local marine reservoir correction cannot be used. The only direct evidence of ties to the mainland is a porcupine incisor chisel that was found in the unit wall scrapings.

Faunal remains occur throughout these deposits including the black silt that underlies the shell midden deposits. Identifications of the faunal remains were undertaken at the University of Victoria faunal laboratory. Rebecca Wigen of Pacific Identifications, Inc. identified and supervised my identifications for all elements

excavated from a 1 x 1 m sample of the excavation unit. The total numbers of specimens identified of bird, fish, sea mammal, and land mammal that were found are listed in Table 14. One of the three column samples taken was sent to UBC where Richard Bolton analyzed invertebrate remains (Bolton 2007). One column sample was sent to Natalie Brewster at McMaster University who is undertaking an intra-site comparison of faunal remains (Burchell and Brewster 2007).

Figure 91. Bone artifacts from excavation units AA and AB, GcTr-6.



Shells from Far West Point include clam species (*S. giganteus*; *Protothaca stamina*, *P. laciniata*, *Tresus* species), barnacle (*Balanus* species), cockle (*Clinocardium*

nutalli), green sea urchin (*Strongylocentrotus droebachiensis*), Pacific blue mussel (*Mytilus trossulus*) and hairy Oregon triton (*Fusitriton oregonensis*). Some of the deposits, in particular at the top of the midden contained largely unbroken shell valves and little soil or matrix. Quantification of shell species from a column sample, screened using a 2 mm mesh, found barnacles and clams to be the most abundant in the shell assemblage:

The mollusk remains in Column Sample 2 are comprised of primarily 7 mollusk species with trace amounts of a few other species. There is a considerable dominance in the weight of barnacle throughout the entire shell deposit, representing 65.56% of the total shell weight. The next most prominent species is butter clam/horse clam, which represent 20.07% of total shell weight. These two clam species were combined into one category of clam because it is difficult to distinguish between the two species when umbos are not present, which was the case in this analysis of fragmented mollusk remains. Two other mollusk species that are significant contributors to the total shell weight are cockle (8.27%) and mussel (2.76%). Other species that are present throughout the shell midden include urchin, chiton, littleneck clam, limpet, hairy oregon triton, oyster, and abalone (in decreasing order of importance) [Bolton 2007: 1].

Table 14. Number of identified of faunal remains collected from GcTr-6, 1 x 1 m excavation unit (3 mm mesh).

GROUP	NSP
Bird	200
Fish	3716
Mammal	20
Land mammal	5
Sea mammal	60
Total	4002

Fish remains make up 93% of vertebrate fauna recovered from the 1 x 1 m sample using a 3 mm mesh for screening. A total of 15 different taxa of fish were identified (Table 15). Clearly the inhabitants at this site had a maritime-oriented subsistence economy. The most common fish remains are those of rockfish. All fish species identified can be caught in the waters surrounding Far West Point. All of the salmon bones come from the lowermost levels of the site.

Table 15. Fish remains recovered from GcTr-6, 1 x 1 m unit excavation using a 3 mm mesh.

Common Name	Taxon	NSP
Buffalo sculpin	<i>Enophrys bison</i>	2
Great sculpin	<i>Myoxocephalus polyacanthocephalus</i>	2
Flatfish species	<i>Pleuronectiformes</i>	7
Gadid (NH)	Gadidae, not hake	52
Greenling species	<i>Hexagrammos</i> species	28
Halibut	<i>Hippoglossus stenolepis</i>	6
Herring	<i>Clupea pallasii</i>	56
Pacific cod	<i>Gadus macrocephalus</i>	7
Pollock	<i>Theragra chalcogramma</i>	2
Prickleback species	<i>Lumpenus</i> species	3
Red Irish lord	<i>Hemilepidotus hemilepidotus</i>	3
Rockfish species	<i>Sebastes</i> species	358
Salmon	<i>Oncorhynchus</i> species	11
Skate	<i>Raja</i> species(unident)	2
Starry flounder	<i>Platichthys stellatus</i>	1
Unidentifiable fish	Pisces	3176
Grand Total		3716

Birds make up 5% of the vertebrate fauna collected from the 1 x 1 m excavation unit at Far West Point, representing 21 different bird taxa (Table 16). Of the 200 bird bones collected, 85 could be identified to the family or species level. From these the most common are duck species and other waterfowl although gull remains have a fairly high frequency. Shearwater bones are common only in the lower black silt component of the site. The single raven bone found is an ulna that was ground into an awl.

Table 16. Bird remains recovered from GcTr-6, 1 x 1 m excavation unit using 3 mm mesh.

Common Name	Taxon	NSP
American wigeon	<i>Anas americana</i>	1
Common loon	<i>Gavia immer</i>	1
Common raven	<i>Corvus corax</i>	1
Cormorant species(med)	<i>Phalacrocorax pelagicus</i>	1
Double-crested cormorant	<i>Phalacrocorax auritus</i>	1
Pelagic cormorant	<i>Phalacrocorax pelagicus</i>	1
Duck (lg)	Anatidae (lg)	7
Duck (med)	Anatidae (med)	16
Duck (med-lg)	Anatidae (med-lg)	20
Duck (sm)	Anatidae (sm)	4
Harlequin duck	<i>Histrionicus histrionicus</i>	1
Gull (lg)	<i>Larus species (lg)</i>	6
Gull (med/lg)	<i>Larus species (med/lg)</i>	2
Oldsquaw	<i>Clangula hyemalis</i>	1
Scaup	<i>Aythya marila/affinis</i>	1
Scoter (undet.)	<i>Melanitta species</i>	4
Surf scoter	<i>Melanitta perspicillata</i>	7
Shearwater species(lg)	<i>Puffinus species</i>	4
Shorebird (lg)	Charadriiformes (lg)	1
Shorebird (med)	Charadriiformes (med)	3
Snow goose	<i>Chen caerulescens</i>	2
Unidentified bird	Aves	115
Grand Total		200

The 85 mammalian remains make up 2% of the vertebrate faunal remains recovered at GcTr-6 (Table 17). Of the mammal bones identified, 6% are land mammal bones, 75% are sea mammal bones, and the remaining 19% are bones that were too degraded to classify as land or sea mammal. Of the identified species, *Callorhinus ursinus* (fur seal), *P. vitulina*, and *Enhydra lutris* (sea otter) were found to be the most common. All of these mammalian resources are present on or around the Dundas Islands with the exception of porcupine (*Erethizon dorsatum*). The single porcupine element is the only fauna from all of those collected that indicates a connection with the mainland. This porcupine incisor has been ground into a chisel. The identification of porcupine is

not 100% certain and the element may be a beaver incisor, a species lacking from the assemblage at Far West Point, but which is known to occur on the islands.

Table 17. Mammal remains recovered from GcTr-6, 1 x 1 m excavation unit using a 3 mm mesh.

Common Name	Latin Name	NSP
Carnivore species (med)	Carnivora	1
Fur seal	<i>Callorhinus ursinus</i>	3
Harbour seal	<i>Phoca vitulina</i>	5
Mink	<i>Mustela vison</i>	3
Northern sea lion	<i>Eumetopias jubata</i>	1
Porcupine	<i>Erethizon dorsatum</i>	1
Sea otter	<i>Enhydra lutris</i>	6
Whale species	Cetacea	1
Undetermined mammal	Mammalia	20
Undetermined sea mammal	Mammalia	44
Grand Total		85

Discussion

Five archaeological sites were found pre-date 5,000 years BP on raised landforms. Four of these sites occur with later Holocene occupational evidence generally located on lower elevation landforms; all are shell middens. These are the first pre-5,000 BP archaeological sites to have been found in the Hecate Lowlands region of British Columbia. Archaeological sites in Prince Rupert Harbour post-date 5,000 BP (Fladmark et al. 1990). Archaeological prospection in inland areas also found considerable use of raised landforms throughout the late-Holocene. The results of archaeological prospection, combined with excavations undertaken at Far West Point provide insights into the early Holocene archaeology of the region.

Technology

Although predating the archaeological deposits from Prince Rupert Harbour by 1,000 to 3,000 years, and lacking ground stone implements, the collection of cultural material excavated from Far West Point would not be out of place in later Holocene

archaeological contexts (see Ames 2005; Fladmark et al. 1990; MacDonald and Inglis 1981; MacDonald 1969). These remains point to long-term continuity in material cultural production in the Coast Tsimshian region.

Conspicuously absent are microblades from dated contexts, which are common at contemporaneous archaeological sites at Namu (Carlson 1996a), on Haida Gwaii (Fedje and Christensen 1999; Christensen and Stafford 2005) and southeast Alaska (Ackerman 1996b). The reasons for the lack of microblade technology may be the result of functional differences between these sites and Far West Point. The poor quality of lithic material on the Dundas Islands and the small amount of area sampled may also be a contributing factor. One microblade fragment was found during shovel testing of a raised terrace on the southwest side of Dunira Island (GcTq-3) suggesting that the technology is not completely absent from the area.

The spall, flakes, cobble core, and cobble chopper found on raised marine features on the north Melville isthmus (GcTq-2), and lithics from GdTr-4, are common artifact types throughout the entire Holocene.

Subsistence

Detailed analyses of faunal remains were undertaken on samples recovered from excavations at Far West Point. Assemblages of shellfish similar to that found at Far West Point (Bolton 2007) are described for other early Holocene archaeological sites in the region. However these sites differ with respect to the most frequent species found. At Chuck Lake, southeast Alaska (Ackerman 1996b), clam species, *C. nuttalli*, and *M. trossulus*, make up the majority of the shell midden; *Balanus* species are described as a minor constituent. The dominant species at Kilgii Gwaay is California mussel (*M.*

californianus) making up 84% of shell weight (Fedje et al. 2005c). At Cohoe Creek dominant species are described as clam species, *C. nuttalli*, *M. trossulus*, and *S. droebachiensis*; again *Balanus* species is relegated as a more minor part of the assemblage. Similar to the Far West Point assemblage, there is predominance of *Balanus* species in the shell midden at Kit 'n' Kaboodle Cave in southeast Alaska (Moss 2008, personal communication)

The low frequency of salmon differentiates this site from the contemporaneous Cohoe Creek site on Graham Island where jack mackerel (*Trachurus symmetricus*) and *Oncorhynchus* species are the dominant fish taxa (Christensen and Stafford 2005). Later Holocene village sites on the Dundas Islands have higher incidences of salmon and some oolichan, although sites interpreted as residential camps, including Far West Point, appear to have lesser frequencies of anadromous species (Burchell and Brewster 2007). The high incidence of bottomfish at Far West Point is consistent with north coastal areas that lack highly productive salmon streams such as both early and late Holocene sites in Gwaii Haanas (Acheson 1998; Steffen 2006). Faunal remains from Chuck Lake on Heceta Island are reported as being dominated by 89.2% bottomfish including: *G. macrocephalus*, *Hexagrammos* species, *H. hemilepidotus*, and *Sebastes* species (Ackerman 1996b).

These outer coast and small island site contexts can be contrasted with the early Holocene archaeofauna at Namu on the mainland central coast of British Columbia. The site is situated at the mouth of the Namu River and the fish assemblage is dominated by *Oncorhynchus* species, although bottomfish are present in small numbers (Cannon 1996). The eleven *Oncorhynchus* species bones at Far West Point occur only in the lower black

silt deposits (255-275 cm db). As with other early-Holocene sites in the area, the early Holocene fauna at Far West Point appears to reflect localized biogeographic distributions. Fishing technology of outer coast and island populations appears to have been geared towards capturing bottomfish. In areas close to major salmon streams, in and near-stream technologies focused on salmon procurement.

The percentage of bird bone from GcTr-6 and types of bird remains are similar to those found at Coho Creek (Christensen and Stafford 2005). At Chuck Lake, birds constituted 3.4% of the faunal remains. At Namu, birds are described as a supplementary food resource (<1%) dominated by Anatidae remains (Cannon 1996). Combined, these results suggest a difference between early Holocene archaeological sites located on outer coastal islands and the inner coast, as there is a greater reliance on a diversity of birds in outer coastal areas (Moss 2004b).

The lack of large land mammals in the assemblage is likely due to the paucity of large land mammals on the Dundas Islands. Higher sea levels in late Pleistocene and early Holocene times may have contributed to this lack of land mammals by reducing the land base. This is striking when considering the overall percentage of land mammal bones in the assemblage at Coho Creek is 34%, dominated by caribou and black bear (Christensen and Stafford 2005). *O. hemionus* dominates the land mammal bones at Namu, which make up 4.5% of the assemblage at Namu (Cannon 1996). At Far West Point the overall percentage of land mammals is 0.01% and made up of small mammals. The lack of land mammal resources appears to have been compensated for through increased harvesting of fish and shellfish.

Overall, the fauna reveal a generalized subsistence economy derived exclusively from locally available resources and, unlike the contemporaneous components from Haida Gwaii, Chuck Lake, and Namu, the Far West Point assemblage lacks significant land mammal remains.

Sea Levels and Settlement Patterns at Far West Point

Excavations at Far West Point revealed that cultural deposits occur under the maximum extent of visible shell deposits. These underlying sediments may date as old as 9,690 BP. Similar older, non-shell strata occur under two of the other three shell midden sites that date older than 5,000 BP. These sediments may have once contained shell but the shell may have leached out as a result of prolonged contact with acidic ground water. Alternatively, early cultural deposition at the site may have included shell but not enough of it to render soils alkaline so as to preserve shell in the sediments. However, the presence of bone in the non-shell midden cultural layers at Far West Point suggests that conditions were favourable for bone preservation and were not likely acidic.

Overall, the archaeological remains from Far West Point reveal a pattern of long-term occupation of the site. As sea levels regressed, settlement appears to have followed. The initial occupation appears to have occurred on the highest terrace between 9,960 and 6,185 BP (Figure 92). The lowest deposits associated with this occupation are located 8.25 m aBl, above the early Holocene stillstand identified through isolation basin coring.

The occupational remnants are not large and the site was likely used only seasonally. The presence of young juvenile and juvenile *P. vitulina* and *E. lutris* remains suggests a late spring or summer occupation, although most of the species found are not

seasonally diagnostic. A generalized approach to subsistence appears to have been practiced with the remains of shellfish and fish predominating in the assemblage.

Following 6,185 BP the upper terrace appears to have been abandoned (Figure 93). This period of abandonment occurs at about the time of the fall of sea level around 5,500 BP. Evidence of occupation reappears in the former intertidal zone dating between 3,645 and 2,755 BP. The lowest midden deposits at this locality are 3.2 m abl. The most recent occupation at the site is a cabin, located just above the present day shoreline (2 m abl) made accessible by further shoreline regression since 3,000 BP (Figure 94).

Sea Levels and Settlement Patterns at other Locations

Three additional archaeological sites were found to have co-occurring early and late Holocene components: GdTq-3, GcTq-4, and GcTr-8. This pattern of co-occurrence differs from that found in southern Haida Gwaii where early and late Holocene sites were rarely found to co-occur (Mackie and Sumpter 2005). The reason for these differences may be the result of a larger temporal gap (~8,000 years) between the early and late Holocene sites compared in Haida Gwaii.

Other archaeological deposits were found to occur on raised sedimentary features in the study area. However, radiocarbon dating of these deposits revealed that they represent later Holocene usage of inland areas, for dumping shell, and possibly for refuge, seclusion, secret societal functions, and, in the case of the Connel Island Dune site, as a refuge and lookout.

Figure 92. GcTr-6, vegetation line at 6 m abl (map created by Susan Formosa).

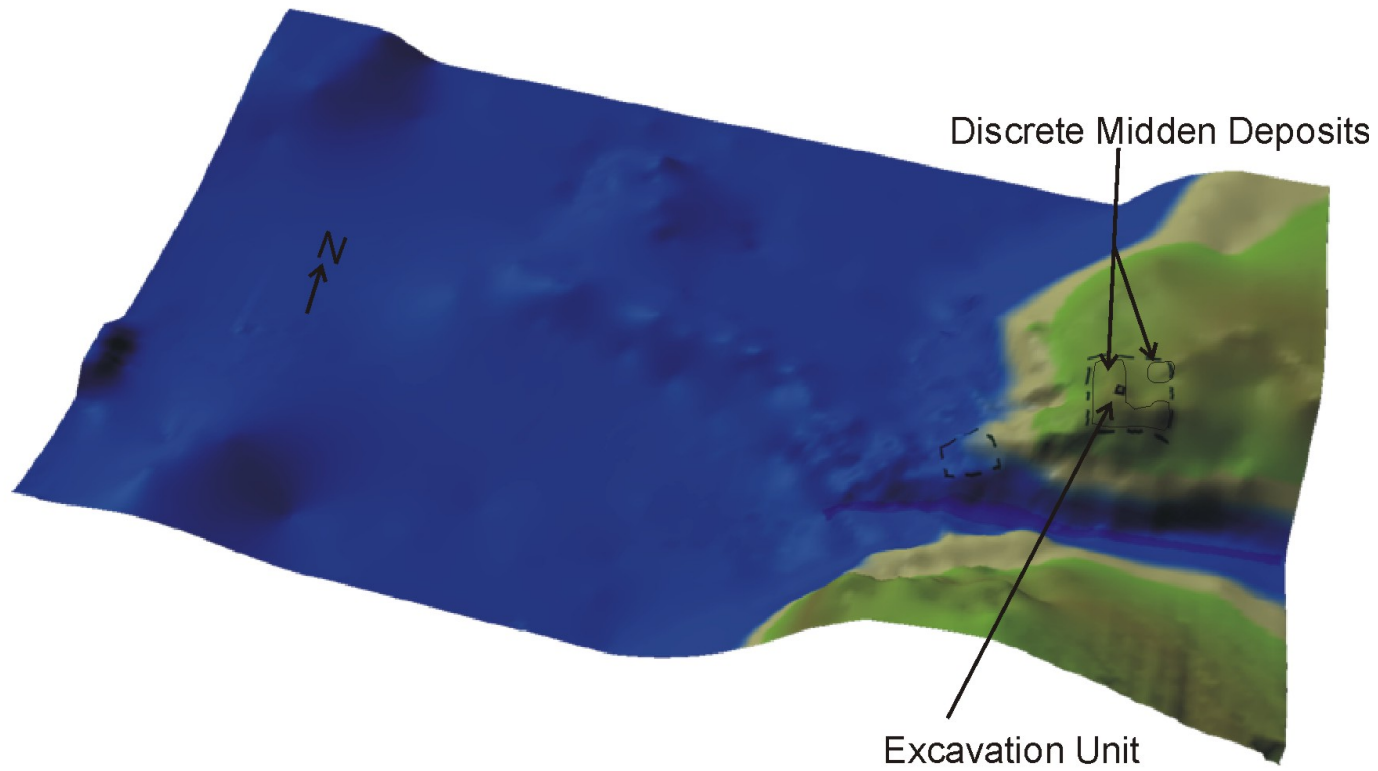


Figure 93. GcTr-6, vegetation line at 4 m abl (map created by Susan Formosa).

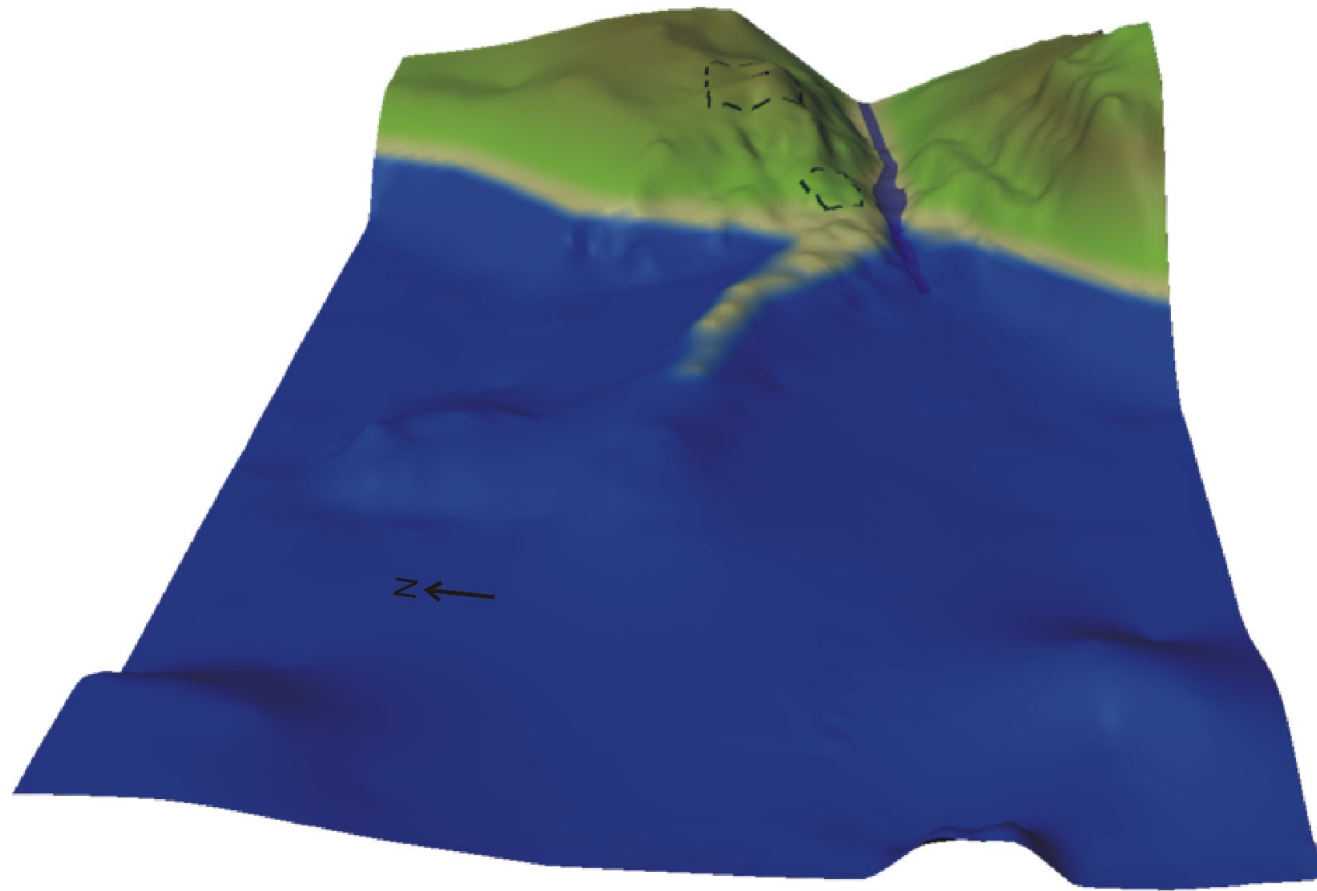
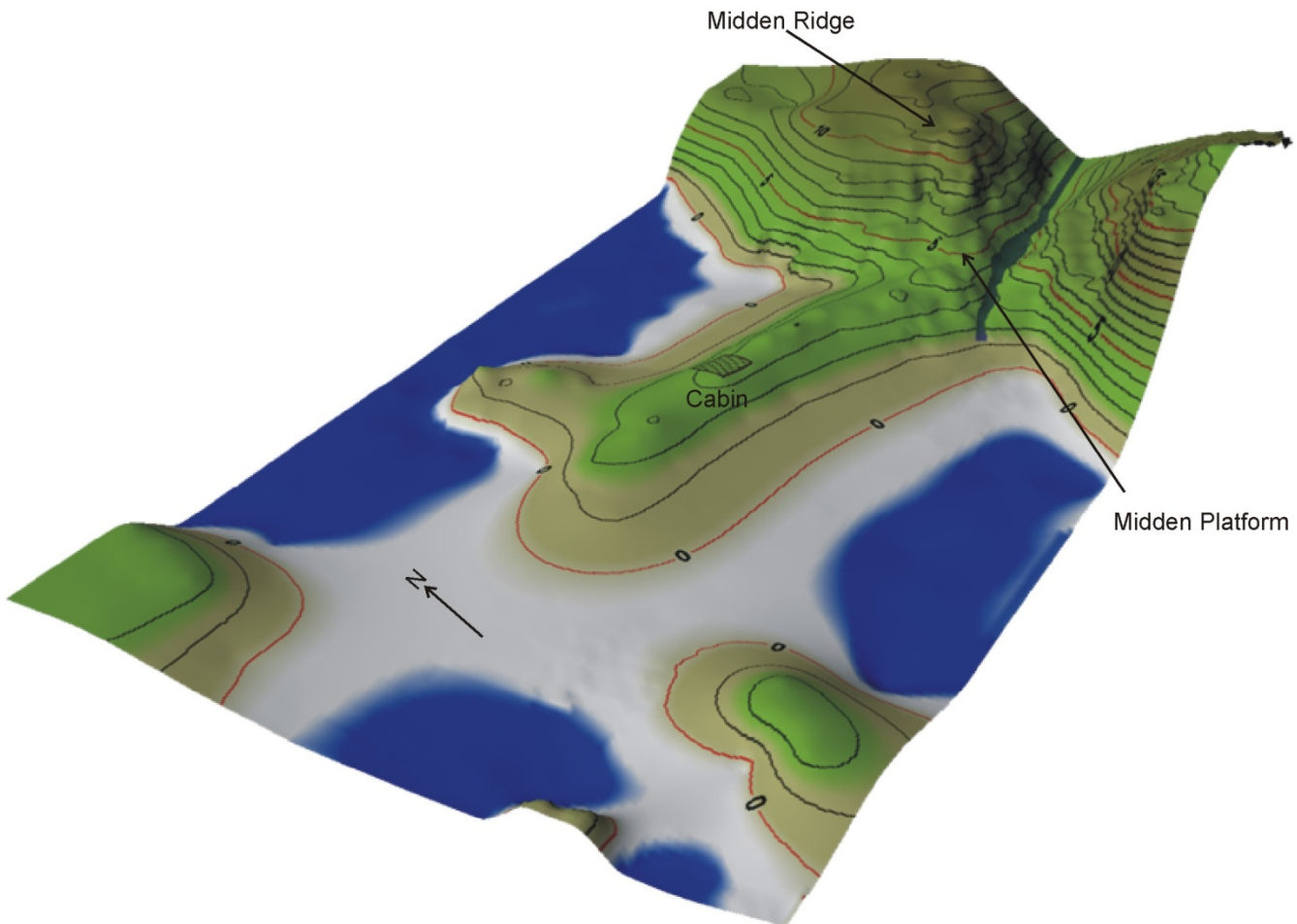


Figure 94. GcTr-6, vegetation line at 2 m abl, (map created by Susan Formosa).



Deposits with low frequencies of archaeological remains were found in the west of Baron rock shelter 1 and on the north Melville Isthmus. These archaeological remains are above 14 m abl, but remain undated. It is possible, but not certain, that archaeological material located in the sediments of these features dates to the early period. Prior to research undertaken on the Dundas Island project, no sites pre-dating 5,050 BP had been located in Coast Tsimshian territory.

*Chapter IX –Conclusions Regarding Palaeo-Environments and
Archaeology on the Dundas Island Archipelago*

From the outset, the primary goal of this interdisciplinary dissertation was to locate late Pleistocene and early Holocene archaeological sites on the Dundas Island Archipelago using palaeo-shorelines as a guide. The study area was chosen for this project as it was hypothesized that late Pleistocene and early Holocene shorelines in the region were located only a few metres higher than present-day sea level as a result of global eustatic and local glacial isostatic processes. The two primary hypotheses that were tested by this dissertation research project are: (1) the Dundas Island Archipelago lies in a sea level hinge region of north coastal British Columbia; and, (2) that archaeological sites dating to the late Pleistocene and early Holocene could be found on the relatively stable raised shorelines of this hinge region.

In pursuit of this primary goal, four research strategies were designed and carried out: (1) reconstruction of vegetation history of the Dundas Islands through pollen analysis; (2) identification of relict shores and the creation of a relative sea level curve for the Dundas Island Archipelago; (3) compilation of geographic data to select areas where archaeological sites were expected to be most common; and (4) archaeological prospection for sites dating to the late Pleistocene and early Holocene. This dissertation describes the results of these research strategies.

The results of the vegetation history construction reveal that the islands have been vegetated for at least 13,000 years. Late Pleistocene vegetation communities appear to have undergone significant changes before stabilizing during the Holocene. Despite

these abrupt changes, the climate of the Dundas Island area could have permitted human habitation since at least 13,000 BP, although early environments were likely scant. The sequence of vegetation communities is in some respects distinct from that of other regions which have been analyzed on the north coast of British Columbia and in southeast Alaska. In particular, Cupresaceae is found to occur in moderate amounts after 10,000 BP, whereas *Picea* and *T. heterophylla* are only present in low quantities. Similar to later Holocene cultures, early Holocene inhabitants of the Dundas Islands could access at least some cedar (most likely *C. nootkatensis*) for technological needs. The mid-Holocene increase in cedar pollen can be attributed to the appearance of *T. plicata* on the north coast of British Columbia at this time (Hebda and Mathewes 1984).

Beginning in the early Holocene, the increasing paludification of areas with flat topography may have had an impact on the choice of location for setting up suitable habitation sites. The very poor drainage and saturated soils likely contributed to the use of shell waste as substructural and floor material and the stockpiling of this raw material in mounds and ridges. Better drainage resulting from accumulations of shell midden rendered the localities attractive over very long periods of time as is seen by the long-term use and co-occurrence of site locations in the study area.

Sea level research described here lends support to the hypothesis that the Dundas Islands lies in a sea level hinge area. Overall, evidence from geomorphic features, sedimentary sections, and in particular lake cores, reveals that sea levels were between 13 and 15 m abl between 12,385 and 12,100 BP. After this, sea levels began to decline slowly, reaching 10 m abl after 10,320 BP. Shorelines remained above 6 m abl until 5,280 BP after which they fell to present day levels after 3,885 BP. There is currently no

evidence from the Dundas Islands that sea levels fell to elevations that are lower than present, although testing of this has been minimal.

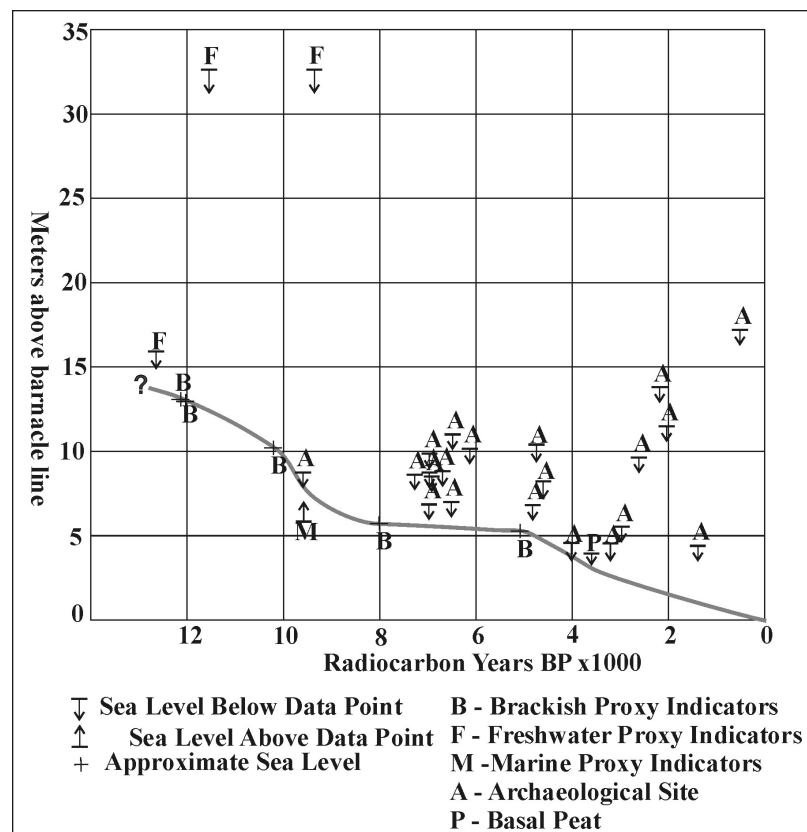
The creation of a relative sea level curve was undertaken to enable the targeting of specific elevations to look for archaeological sites dating to the late Pleistocene and early Holocene. To further aid in this endeavour, a photogrammetrically derived, microtopographic, digital elevation model was acquired for selected parts of the study area. Selection was based on a number of different geographic criteria including: aspect, exposure, slope, distance to fresh water, cave or rock shelter potential, nearness to salmon streams, proximity to later period archaeological site locations, and physical shore zone type. With the compilation of this information, palaeo-shoreline maps were generated from the 2 m contour data.

Guided by the palaeo-shoreline maps, archaeological survey and prospection was undertaken on relict shorelines of the Dundas Islands. Five archaeological sites dating to the early Holocene were located: GdTq-3, GcTq-4, GcTr-6, GcTr-8, and GcTq-2. No directly dated archaeological sites dating to the late Pleistocene period were identified, although some lithics were discovered in beach sand are suspected of being deposited before 10,000 BP, in particular at GcTq-2. A low density of possible cultural remains was also found in the undated sediments of a rock shelter lying 20 m abl, GdTr-4. Other archaeological deposits were found at elevations above the early Holocene stillstand on the islands, but date to the late Holocene. Some lower elevation archaeological sites were also encountered and dated. All archaeological sites have elevations and dates that are consistent with the sea level curve generated for the Dundas Islands.

Whereas the sea level curve was generated in order to help find archaeological sites, the documentation of basal elevations and radiocarbon dates of archaeological deposits can be used to support the accuracy and validity of the sea level curve (Figure 95).

In contrast to the relatively stable history of sea levels for the study area, terrestrial areas underwent marked shifts in vegetation communities that tend to be reflected in other parts of the Dixon Entrance and Hecate Strait region. This history of vegetation lends support to the deglacial and isostatic sequence of events that has been proposed for the region, revealing that the Dundas Islands were deglaciaded by at least 13,000 BP and have remained so since that time.

Figure 95. Sea level curve for the Dundas Island Archipelago derived from palaeo-environmental and archaeological data points.



The methods employed in this research project were successful in achieving the goal of identifying early Holocene relict shorelines on the Dundas Island Archipelago. As hypothesized, the study area lies near a sea level hinge and sea levels have been relatively stable compared to areas farther to the west and east. Archaeological prospection methods revealed archaeological deposits associated with the relict shoreline. Dates on these archaeological deposits have revealed the first evidence of pre-5,000 BP human occupation in Coast Tsimshian Territory.

Limitations

This project was interdisciplinary and drew upon multiple lines of inquiry in order to address its goals. For the most part, the methods of the pollen and diatom analyses were learned as a part of this dissertation project. I had support and guidance in the identification process. Dr. Richard Hebda was very helpful in clarifying my identifications of unfamiliar pollen. Daryl Fedje helped me in diatom identifications. In both pollen and diatom identification, the first slides that I counted were returned to at a later date and questionable identifications were verified.

While this research project demonstrated that the sea levels of the Dundas Islands have remained relatively stable, the geographic extent of this hinge area remains unknown. Certainly the relatively similar pattern of sea level change from southern and northern Haida Gwaii (Fedje et al. 2005b) suggests that there is at least some consistency from northwest to southeast. Variation in sea level history is greater from northeast to southwest, perpendicular to the margin of the Northwest Coast. Based on the compilation of over 300 dated and undated references to sea levels in southeast Alaska (Jim Baichtal 2007, personal communication), a similar pattern of variation from northeast to southwest

was found with the suspected sea level hinge being located in the vicinity of Clarence Strait, which trends southeast to northwest.

The sea level curve generated in this research project may not be applicable to areas beyond the Dundas Islands. Deviation will likely be greatest from southwest to northeast.

Despite the accessible and identified relict shorelines of the Dundas Islands, archaeological sites dating to the late Pleistocene time period were not found with certainty. The reasons for this may be due to several factors: more time was spent testing lower elevation features, subsurface testing was not undertaken to sufficient depths, and the possibility that such deposits are rare or lacking in the study area. Regardless, the discovery of low density, undated, and slightly ambiguous archaeological materials in deposits above 14 m is intriguing.

With the exception of Far West Point, basal dates for shell midden sites cited in this text do not necessarily date the base of cultural occupation. As found in excavations at Far West Point, deposits below shell middens can contain cultural bearing matrices. For this reason, it is likely that several of the dated shell midden sites found during this project have lower and older components.

The conflicting basal dates from Far West Point make it difficult to determine with certainty the age of basal deposits at the site. Further testing and more careful excavation and sampling of these basal deposits is warranted. Early Holocene deposits found beneath shell middens at Namu (Carlson 1996a), Hidden Falls (Davis 1996), and Ground Hog Bay (Ackerman 1996a) all have dates between 10,000-9,000 BP and 8,000-

7,000 BP in their lowest strata and cultural components. The 9,690 BP date is not unreasonable in the regional or geoarchaeological context.

Early Holocene Occupation on Dundas Island

The excavation from Far West Point and testing at other midden sites reveal that early Holocene occupants of the Dundas Islands accumulated large heaps of shell in the vicinity of their habitations. Residents appear to have relied almost exclusively on locally available resources when occupying Far West Point. The diversity of species found reveals that a generalist approach to resource acquisition was practiced rather than a more specialist approach as is often associated with salmon-rich late-Holocene assemblages. The lack of land mammal remains in the collection likely reflects the lack of locally available species on the Dundas Islands. Lithic objects are infrequent, possibly a result of the poor quality of locally available raw materials.

Overall, the Far West Point site reflects an almost exclusively maritime adaptation, more so than the later period sites located in the Prince Rupert Harbour region. Additionally, no ground stone items were recovered. With the exception of this, the technological component found in the early Holocene deposits at Far West Point, including objects of bone and stone, would not be out of place in later Holocene contexts in the Prince Rupert Harbour region suggesting long-term cultural and material continuity. The location of three occupations at different elevations at Far West Point provides a concise example of changing settlement patterns as a result of changing sea levels. By correlating the Dundas Island sea-level history with the chronology of habitation at this site, it was possible to account for the changes in occupation as resulting from human response to sea-level change.

A Mosaic of Multiple Historical Narratives

The oral historical, palaeo-environmental, and archaeological records of the Northwest Coast of North America reveal that in the past there have been changes in sea level. The oral historical and archaeological records reveal that such changes affected human populations that lived on the coast.

It is impossible to directly radiocarbon date an oral historical event and, for this reason, a quantitative comparison of the timing of the sea level changes as related by these different approaches is not possible. This is not to say, however, that oral history is atemporal. On the contrary, events related in many of these narratives are strung together using sequencing references and genealogical ordering (Marsden 2002; McLaren 2003). In this manner, an overarching sequence of geological, genealogical, mythological, and migration events is used to reference when a particular story takes place, for example, “this story occurred before the flood”. The sequential ordering of events related in the oral histories of the Tsimshian, Haida, and Tlingit has long been a concern of ethnographers (Boas 1916; Bringhurst 2000; Marsden 2000; Swanton 1905).

Scholars working in the region have recognized the overall importance of events related in oral narratives and have either adopted research projects directly oriented at revealing archaeological correlates (Archer 2001; Martindale and Marsden 2003) or have examined the archaeological and palaeo-environmental records in relation to specific events related in the oral histories (Fedje and Christensen 1999; Fladmark 1989; Kii7iljuus and Harris 2005; Marsden 2000; Martindale and Marsden 2003).

As revealed through palaeo-environmental research, the isostatic depression of the Northwest Coast resulted in marked differences in sea levels at a localized level (Clague

et al. 1982; Clague 1984; Fedje et al. 2004a; Fedje et al. 2005b; Hetherington 2002). People inhabiting the different regions of this landscape during the early Holocene and late Pleistocene would have had markedly different experiences of sea level history. To the west, on Haida Gwaii, sea levels rose abruptly during terminal Pleistocene times. To the east, on the mainland of North America, sea levels were dropping at the same time. As revealed through research undertaken in this dissertation, sea levels in the region in between were relatively stable. Early human populations on the Dundas Islands would have experienced relatively gradual sea level fall that was likely barely perceptible. However, 100 km to the west, the sea level rose 160 m over 3,000 years, on average 3 m every 60 years (Fedje et al. 2005b). This rate of sea level rise would have undoubtedly been noticeable to people inhabiting the region, whose elders, in many cases, would not have been able to inhabit the houses in which they were born because of inundation. Conversely, on the mainland and in the vicinity of the Nass River, 100 km to the east of the Dundas Islands, sea level dropped, on the order of 230 m since deglaciation (McCuaig and Roberts 2002). Such events would have meant that a coastally oriented settlement would have been stranded inland and populations would have been forced to continuously move their residences down slope in order to maintain their residences on the shoreline. Associated with this time of deglaciation and regression between 12,500 and 9,000 BP, areas such as the lower Skeena River would have been fjords that dried up becoming river valleys (Clague 1984).

These markedly different patterns of sea level change are possibly reflected by differences in the oral historical narratives of the region. In the Haida sequence, language and lineage dispersion on the coast occurred before the last deluge (Bringhurst 2000;

Swanton 1905). In the Tsimshian sequence, the dispersal of languages and lineages occurred after the deluge (Marsden 2000). As found in other parts of the Northwest Coast, it is possible that some or all of the events may be the result of shorter term catastrophes such as tsunamis (Bornhold et al. 2007; McMillan and Hutchinson 2002). However, archaeological research has revealed physical evidence that people were living on the Northwest Coast at this time of fluctuating sea levels at least by 10,500 BP (Fedje et al. 2004b). Furthermore, having experienced these different events, and with mnemonic devices such as geological deposits with shell bearing sediments, it is not impossible that the oral historical record would reflect isostatically induced events of sea level change. Significantly, the deluge stories of the Haida, Tsimshian, and Tlingit reflect the human experience of sea level change, whether short term or long term, and not the diffusion of this mythical motif from western Asia. The historical importance of the deluge story amongst western scholars may have influenced their desire to record it after a period of intense missionization on the Northwest Coast, but regardless of a few adopted motifs, the oral historical record of sea level change relates the experienced and observed events that occurred after the region was deglaciated.

Field and analytical research presented in this dissertation examine localized events of sea-level and human settlement history in the sea level hinge area of the north coast of British Columbia. Whereas it has been suggested here that the events associated with rapid sea-level change to the east and west of the study area were so impressive that they were incorporated into the long-term oral historical record of the region's inhabitants, sea-level change on the Dundas Islands was relatively minimal in comparison and likely relatively imperceptible. The gentle regression of shorelines on the Dundas

Islands did, however, necessitate the implementation of some adaptive strategies. The examples of adaptation to sea level regression from Far West Point, and other sites found during field research reveal that human occupants re-established their settlements so as to remain at the margins of the shoreline as ocean levels regressed through the Holocene period.

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Appendix A – Radiocarbon Date

Calibrations

Radiocarbon date calibrations made using:
CALIB RADIOCARBON CALIBRATION
PROGRAM Copyright 1986-2005 M. Stuiver
and P.J. Reimer

Delta R corrections used are 200 years based
on the findings of Southon and Fedje (2003).

Dates are ordered chronologically from
youngest to oldest.

Palaeo-environmental Samples

UCIAMS 21986

Wood

Radiocarbon Age 3885±20

Calibration data set: intcal04.14c

Reimer et al. 2004

One Sigma Ranges: [start:end] relative area
[2456 BC:2417 BC] 0.385375
[2409 BC:2342 BC] 0.614625

Two Sigma Ranges: [start:end] relative area
[2462 BC:2299 BC] 1.

UCIAMS 23807

Seeds, insect part, needle

Radiocarbon Age 5280±100

Calibration data set: intcal04.14c

Reimer et al. 2004

One Sigma Ranges: [start:end] relative area
[4233 BC:4035 BC] 0.868317
[4024 BC:3992 BC] 0.131683

Two Sigma Ranges: [start:end] relative area
[4340 BC:3941 BC] 0.985761
[3856 BC:3843 BC] 0.006433
[3837 BC:3820 BC] 0.007805

CAMS 82216

Plant macrofossil

Radiocarbon Age 8000±300

Calibration data set: intcal04.14c

Reimer et al. 2004

One Sigma Ranges: [start:end] relative area
[7312 BC:6595 BC] 1.

Two Sigma Ranges: [start:end] relative area
[7589 BC:6343 BC] 0.989139
[6313 BC:6259 BC] 0.010861

CAMS 82219

Leaf fragment

Radiocarbon Age 9570±80

Calibration data set: intcal04.14c

Reimer et al. 2004

One Sigma Ranges: [start:end] relative area
[9138 BC:8972 BC] 0.551385
[8941 BC:8807 BC] 0.448615

Two Sigma Ranges: [start:end] relative area
[9228 BC:8732 BC] 1.

CAMS 87244

Leaf fragment

Radiocarbon Age 9520±60

Calibration data set: intcal04.14c

Reimer et al. 2004

One Sigma Ranges: [start:end] relative area
[9120 BC:9004 BC] 0.468094
[8917 BC:8896 BC] 0.072641
[8863 BC:8751 BC] 0.459266

Two Sigma Ranges: [start:end] relative area
[9150 BC:8704 BC] 0.984998
[8672 BC:8654 BC] 0.015002

CAMS 82217

Plant macrofossil

Radiocarbon Age 9735±40

Calibration data set: intcal04.14c

Reimer et al. 2004

One Sigma Ranges: [start:end] relative area
[9270 BC:9210 BC] 1.

Two Sigma Ranges: [start:end] relative area
[9290 BC:9147 BC] 1.

UCIAMS 24510

Leaf and needles

Radiocarbon Age 10320±40

Calibration data set: intcal04.14c

Reimer et al. 2004

One Sigma Ranges: [start:end] relative area
[10393 BC:10374 BC] 0.065797
[10287 BC:10255 BC] 0.128873
[10226 BC:10091 BC] 0.805329

Two Sigma Ranges: [start:end] relative area
[10422 BC:10316 BC] 0.180493
[10296 BC:10039 BC] 0.819507

UCIAMS 31733
 Pine needles
 Radiocarbon Age 10565±50
 Calibration data set: intcal04.14c
 # Reimer et al. 2004
 One Sigma Ranges: [start:end] relative area
 [10771 BC:10637 BC] 0.667094
 [10518 BC:10453 BC] 0.332906
 Two Sigma Ranges: [start:end] relative area
 [10820 BC:10596 BC] 0.636772
 [10589 BC:10447 BC] 0.363228

CAMS 82218
 Plant macrofossil
 Radiocarbon Age 11490±45
 Calibration data set: intcal04.14c
 # Reimer et al. 2004
 One Sigma Ranges: [start:end] relative area
 [11429 BC:11335 BC] 1.
 Two Sigma Ranges: [start:end] relative area
 [11477 BC:11297 BC] 1.

CAMS 82220
 Plant macrofossil
 Radiocarbon Age 12135±40
 Calibration data set: intcal04.14c
 # Reimer et al. 2004
 One Sigma Ranges: [start:end] relative area
 [12104 BC:11979 BC] 1.
 Two Sigma Ranges: [start:end] relative area
 [12157 BC:11905 BC] 1.

UCIAMS 24508
 Moss and seeds
 Radiocarbon Age 12170±160
 Calibration data set: intcal04.14c
 # Reimer et al. 2004
 One Sigma Ranges: [start:end] relative area
 [12310 BC:11845 BC] 1.
 Two Sigma Ranges: [start:end] relative area
 [12803 BC:11758 BC] 1.

UCIAMS 30933
 Pine needles
 Radiocarbon Age 12250±500
 Calibration data set: intcal04.14c
 # Reimer et al. 2004
 One Sigma Ranges: [start:end] relative area
 [13047 BC:11743 BC] 1.
 Two Sigma Ranges: [start:end] relative area
 [13723 BC:11232 BC] 1.

UCIAMS 24509
 Seeds and pine needles
 Radiocarbon Age 12385±30
 Calibration data set: intcal04.14c
 # Reimer et al. 2004
 One Sigma Ranges: [start:end] relative area
 [12522 BC:12229 BC] 1.
 Two Sigma Ranges: [start:end] relative area
 [12751 BC:12184 BC] 1.

UCIAMS 12385
 Seed
 Radiocarbon Age 12385±30
 Calibration data set: intcal04.14c
 # Reimer et al. 2004
 One Sigma Ranges: [start:end] relative area
 [12522 BC:12229 BC] 1.
 Two Sigma Ranges: [start:end] relative area
 [12751 BC:12184 BC] 1.

Archaeological Samples

UCIAMS 21983
 Charcoal
 Radiocarbon Age 640±60
 Calibration data set: intcal04.14c
 # Reimer et al. 2004
 One Sigma Ranges: [start:end] relative area
 [1286 AD:1323 AD] 0.440494
 [1346 AD:1393 AD] 0.559506
 Two Sigma Ranges: [start:end] relative area
 [1272 AD:1413 AD] 1.

UCIAMS 21880
 Mussel shell
 Radiocarbon Age 1395±15
 Delta R = 200±60
 Calibration data set: marine04.14c
 # Hughen et al. 2004
 One Sigma Ranges: [start:end] relative area
 [1157 AD:1282 AD] 1.
 Two Sigma Ranges: [start:end] relative area
 [1065 AD:1305 AD] 1.

UCIAMS 21987

Seeds

Radiocarbon Age 1815±35

Calibration data set: intcal04.14c

Reimer et al. 2004

One Sigma Ranges: [start:end] relative area

[138 AD:198 AD] 0.640729

[206 AD:238 AD] 0.359271

Two Sigma Ranges: [start:end] relative area

[89 AD:102 AD] 0.017721

[123 AD:260 AD] 0.908511

[283 AD:323 AD] 0.073768

BETA 215182

Shell

Radiocarbon Age 2390±40

Delta R = 200±60

Calibration data set: marine04.14c

Hughen et al. 2004

One Sigma Ranges: [start:end] relative area

[80 AD:254 AD] 1.

Two Sigma Ranges: [start:end] relative area

[13 BC:352 AD] 1.

BETA 215181

Shell

Radiocarbon Age 2440±50

Delta R = 200±60

Calibration data set: marine04.14c

Hughen et al. 2004

One Sigma Ranges: [start:end] relative area

[14 AD:209 AD] 1.

Two Sigma Ranges: [start:end] relative area

[95 BC:305 AD] 1.

TO 13288

Butter/ horse clam

Radiocarbon Age 2510±50

Delta R = 200±60

Calibration data set: marine04.14c

Hughen et al. 2004

One Sigma Ranges: [start:end] relative area

[73 BC:123 AD] 1.

Two Sigma Ranges: [start:end] relative area

[173 BC:223 AD] 1.

UCIAMS 28010

Charcoal

Radiocarbon Age 2530±15

Calibration data set: intcal04.14c

Reimer et al. 2004

One Sigma Ranges: [start:end] relative area

[783 BC:754 BC] 0.502327

[685 BC:668 BC] 0.355828

[610 BC:598 BC] 0.141845

Two Sigma Ranges: [start:end] relative area

[789 BC:748 BC] 0.406709

[688 BC:665 BC] 0.267999

[643 BC:588 BC] 0.262129

[582 BC:556 BC] 0.063163

BETA 215175

Shell

Radiocarbon Age 3070±40

Delta R = 200±60

Calibration data set: marine04.14c

Hughen et al. 2004

One Sigma Ranges: [start:end] relative area

[776 BC:580 BC] 1.

Two Sigma Ranges: [start:end] relative area

[823 BC:438 BC] 1.

UCIAMS 21883

Clam shell

Radiocarbon Age 3145±20

Delta R = 200±60

Calibration data set: marine04.14c

Hughen et al. 2004

One Sigma Ranges: [start:end] relative area

[852 BC:712 BC] 1.

Two Sigma Ranges: [start:end] relative area

[913 BC:567 BC] 1.

TO 13291

Butter/ horse clam

Radiocarbon Age 3170±50

Delta R = 200±60

Calibration data set: marine04.14c

Hughen et al. 2004

One Sigma Ranges: [start:end] relative area

[895 BC:726 BC] 1.

Two Sigma Ranges: [start:end] relative area

[986 BC:563 BC] 1.

BETA 215177
 Shell
 Radiocarbon Age 3460±40
 Delta R = 200±60
 Calibration data set: marine04.14c
 # Hughen et al. 2004
 One Sigma Ranges: [start:end] relative area
 [1249 BC:1036 BC] 1.
 Two Sigma Ranges: [start:end] relative area
 [1347 BC:936 BC] 1.

UCIAMS 21985
 Charcoal
 Radiocarbon Age 3645±25
 Calibration data set: intcal04.14c
 # Reimer et al. 2004
 One Sigma Ranges: [start:end] relative area
 [2108 BC:2105 BC] 0.026049
 [2035 BC:1960 BC] 0.973951
 Two Sigma Ranges: [start:end] relative area
 [2131 BC:2085 BC] 0.18101
 [2053 BC:1939 BC] 0.81899

UCIAMS 28011
 Charcoal
 Radiocarbon Age 3880±20
 Calibration data set: intcal04.14c
 # Reimer et al. 2004
 One Sigma Ranges: [start:end] relative area
 [2456 BC:2418 BC] 0.352197
 [2408 BC:2374 BC] 0.315122
 [2368 BC:2362 BC] 0.040811
 [2354 BC:2337 BC] 0.162999
 [2323 BC:2308 BC] 0.128871
 Two Sigma Ranges: [start:end] relative area
 [2460 BC:2297 BC] 1.

UCIAMS 21882
 Clam shell
 Radiocarbon Age 4200±15
 Delta R = 200±60
 Calibration data set: marine04.14c
 # Hughen et al. 2004
 One Sigma Ranges: [start:end] relative area
 [2142 BC:1961 BC] 1.
 Two Sigma Ranges: [start:end] relative area
 [2251 BC:2250 BC] 0.000678
 [2242 BC:1884 BC] 0.999322

BETA 215176
 Shell
 Radiocarbon Age 4440±50
 Delta R = 200±60
 Calibration data set: marine04.14c
 # Hughen et al. 2004
 One Sigma Ranges: [start:end] relative area
 [2492 BC:2272 BC] 1.
 Two Sigma Ranges: [start:end] relative area
 [2603 BC:2158 BC] 1.

BETA 215174
 Shell
 Radiocarbon Age 4780±40
 Delta R = 200±60
 Calibration data set: marine04.14c
 # Hughen et al. 2004
 One Sigma Ranges: [start:end] relative area
 [2926 BC:2726 BC] 1.
 Two Sigma Ranges: [start:end] relative area
 [3023 BC:2614 BC] 1.

BETA 215183
 Shell
 Radiocarbon Age 5230±60
 Delta R = 200±60
 Calibration data set: marine04.14c
 # Hughen et al. 2004
 One Sigma Ranges: [start:end] relative area
 [3526 BC:3335 BC] 1.
 Two Sigma Ranges: [start:end] relative area
 [3632 BC:3236 BC] 0.991774
 [3206 BC:3185 BC] 0.008226

BETA 215179
 Shell
 Radiocarbon Age 5290±40
 Delta R = 200±60
 Calibration data set: marine04.14c
 # Hughen et al. 2004
 One Sigma Ranges: [start:end] relative area
 [3601 BC:3437 BC] 0.924379
 [3420 BC:3404 BC] 0.075621
 Two Sigma Ranges: [start:end] relative area
 [3634 BC:3344 BC] 1.

UCIAMS 30932
 Charcoal
 Radiocarbon Age 6185±20
 Calibration data set: intcal04.14c
 # Reimer et al. 2004
 One Sigma Ranges: [start:end] relative area
 [5210 BC:5205 BC] 0.044102
 [5167 BC:5116 BC] 0.570925
 [5111 BC:5076 BC] 0.384973
 Two Sigma Ranges: [start:end] relative area
 [5215 BC:5192 BC] 0.121086
 [5182 BC:5058 BC] 0.878914

UCIAMS 28009
 Charcoal
 Radiocarbon Age 6390±20
 Calibration data set: intcal04.14c
 # Reimer et al. 2004
 One Sigma Ranges: [start:end] relative area
 [5462 BC:5450 BC] 0.127662
 [5376 BC:5323 BC] 0.872338
 Two Sigma Ranges: [start:end] relative area
 [5466 BC:5404 BC] 0.318864
 [5385 BC:5319 BC] 0.681136

UCIAMS 30931
 Charcoal
 Radiocarbon Age 6490±20
 Calibration data set: intcal04.14c
 # Reimer et al. 2004
 One Sigma Ranges: [start:end] relative area
 [5484 BC:5467 BC] 0.758404
 [5402 BC:5389 BC] 0.241596
 Two Sigma Ranges: [start:end] relative area
 [5488 BC:5463 BC] 0.577384
 [5448 BC:5378 BC] 0.422616

TO 13292
 Charcoal
 Radiocarbon Age 6800±60
 Calibration data set: intcal04.14c
 # Reimer et al. 2004
 One Sigma Ranges: [start:end] relative area
 [5728 BC:5643 BC] 1.
 Two Sigma Ranges: [start:end] relative area
 [5835 BC:5827 BC] 0.006554
 [5812 BC:5617 BC] 0.99111
 [5579 BC:5575 BC] 0.002336

BETA 215178
 Shell
 Radiocarbon Age 6830±70
 Delta R = 200±60
 Calibration data set: marine04.14c
 # Hughen et al. 2004
 One Sigma Ranges: [start:end] relative area
 [5306 BC:5089 BC] 1.
 Two Sigma Ranges: [start:end] relative area
 [5406 BC:4978 BC] 1.

BETA 215180
 Shell
 Radiocarbon Age 6890±50
 Delta R = 200±60
 Calibration data set: marine04.14c
 # Hughen et al. 2004
 One Sigma Ranges: [start:end] relative area
 [5359 BC:5194 BC] 1.
 Two Sigma Ranges: [start:end] relative area
 [5441 BC:5078 BC] 1.

UCIAMS 21984
 Charcoal
 Radiocarbon Age 6925±50
 Calibration data set: intcal04.14c
 # Reimer et al. 2004
 One Sigma Ranges: [start:end] relative area
 [5868 BC:5865 BC] 0.019802
 [5845 BC:5738 BC] 0.980198
 Two Sigma Ranges: [start:end] relative area
 [5971 BC:5954 BC] 0.023026
 [5911 BC:5719 BC] 0.976974

UCIAMS 30930
 Charcoal
 Radiocarbon Age 6940±20
 Calibration data set: intcal04.14c
 # Reimer et al. 2004
 One Sigma Ranges: [start:end] relative area
 [5844 BC:5774 BC] 1.
 Two Sigma Ranges: [start:end] relative area
 [5880 BC:5749 BC] 1.

TO 13289
 Butter/ horse clam
 Radiocarbon Age 7000±60
 Delta R = 200±60
 Calibration data set: marine04.14c
 # Hughen et al. 2004
 One Sigma Ranges: [start:end] relative area
 [5457 BC:5304 BC] 1.
 Two Sigma Ranges: [start:end] relative area
 [5522 BC:5208 BC] 1.

UCIAMS 31730
 Whale bone artifact
 Radiocarbon Age 7300±30
 Delta R = 200±60
 Calibration data set: marine04.14c
 # Hughen et al. 2004
 One Sigma Ranges: [start:end] relative area
 [5690 BC:5566 BC] 1.
 Two Sigma Ranges: [start:end] relative area
 [5750 BC:5497 BC] 1.

UCIAMS 21881
 Mussel shell
 Radiocarbon Age 7510±20
 Delta R = 200±60
 Calibration data set: marine04.14c
 # Hughen et al. 2004
 One Sigma Ranges: [start:end] relative area
 [5889 BC:5745 BC] 1.
 Two Sigma Ranges: [start:end] relative area
 [5967 BC:5699 BC] 1.

UCIAMS 28008
 Charcoal
 Radiocarbon Age 9690±30
 Calibration data set: intcal04.14c
 # Reimer et al. 2004
 One Sigma Ranges: [start:end] relative area
 [9240 BC:9174 BC] 0.96098
 [9164 BC:9160 BC] 0.03902
 Two Sigma Ranges: [start:end] relative area
 [9254 BC:9134 BC] 0.917012
 [8977 BC:8934 BC] 0.082988

Ranges marked with a * are suspect due to impingement on the end of the calibration data set

Reimer, P.J., M.G.L. Baillie, E. Bard, A. Bayliss, J.W. Beck, C. Bertrand, P.G. Blackwell, C.E. Buck, G. Burr, K.B. Cutler, P.E. Damon, R.L. Edwards, R.G. Fairbanks, M. Friedrich, T.P. Guilderson, K.A. Hughen, B. Kromer, F.G. McCormac, S. Manning, C. Bronk Ramsey, R.W. Reimer, S. Remmele, J.R. Southon, M. Stuiver, S. Talamo, F.W. Taylor, J. van der Plicht, and C.E. Weyhenmeyer
 2004 INTCAL04 Terrestrial Radiocarbon Age Calibration, 0-26 cal kyr BP. *Radiocarbon* 46:1029-1058.

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 2004 Marine04 marine radiocarbon age calibration, 0-26 cal kyr BP. *Radiocarbon* 46:1059-1086.

Appendix B – Percentage of Diatom Taxa per Sample Examined and Salinity.

S-LESS Lake

Core	Salinity	Source	Class	Sless	Sless	Sless	Sless	Sless	Sless
Depth				131	141	151	161	167	173
<i>Cymbella sp.</i>	NA		0		2.0		1.1		
<i>Navicula sp.</i>	NA		0				0.3		
<i>Neidium sp.</i>	NA		0					0.3	
<i>Stauroneis sp.</i>	NA		0	9.3					
<i>Synedra sp.</i>	NA		0						
<i>Tabellaria sp.</i>	NA		0					2.4	
<i>Acnantes calcar</i>	Oligohalobe	Campeau et al. 1999	1				9.1		
<i>Acnantes cf. kuelbsii</i>	Fresh	Fallu et al. 2000	1				0.3		
<i>Cymbella ehrenbergii</i>	Fresh	Pienitz et al. 2003	1	67.0	12.7	53.5	0.3	5.5	
<i>Cymbella neocistula</i>	Fresh	Pienitz et al. 2003	1					5.9	
<i>Encyonema hebridicum</i>	Fresh	Pienitz et al. 2003	1				2.8	7.6	
<i>Encyonema neogracile</i>	Fresh	Pienitz et al. 2003	1	4.8			4.3	0.3	
<i>Encyonema silesiacum</i>	Fresh	Pienitz et al. 2003	1				1.7	0.3	
<i>Encyonopsis cesatii</i>	Fresh	Pienitz et al. 2003	1					0.3	
<i>Encyonopsis microcephala</i>	Oligohalobe	Pienitz et al. 2003	1					1.4	
<i>Eunotia sp.</i>			1			1.8	2.8	10.0	
<i>Eunotia flexuosa</i>	Fresh	Fallu et al. 2000	1					5.5	
<i>Eunotia monodon</i>	Halphobe	Lemieux 2001	1					0.3	
<i>Eunotia serra</i>	Fresh	Pienitz et al. 2003	1			1.8		1.0	
<i>Eunotia veneris</i>	Dystrophic	Lemieux 2001	1					0.3	
<i>Fragilaria constricta</i>	Fresh	Fallu et al. 2000	1		26.0				
<i>Fragilaria construens var. pumila</i>	Fresh	Fallu et al. 2000	1				21.9		
<i>Fragilaria lata</i>	Fresh	Fallu et al. 2000	1				27.4		

Core	Salinity	Source	Class	Sless	Sless	Sless	Sless	Sless	Sless
Depth				131	141	151	161	167	173
<i>Frustulia krammeri</i>	Olygohalobe	Pienitz et al. 2003	1						
<i>Frustulia saxinoma</i>	Olygohalobe	Pienitz et al. 2003	1				0.3	0.3	
<i>Gomphenoma constrictum</i>	Fresh	Lemieux 2001	1					1.0	
<i>Gomphenoma gracile</i>	Oligohalobe	Lemieux 2001	1					11.0	
<i>Hannaea arcas</i>	Oliohalobe	Pienitz et al. 2003	1					0.3	
<i>Navicula papula sensu lato</i>	Fresh	Fallu et al. 2000	1				1.1		
<i>Navicula radiosa</i>	Fresh	Fallu et al. 2000	1				2.0		
<i>Pinnularia sp.</i>		Lemieux 2001	1	2.4	2.0				
<i>Pinnularia biceps</i>	Fresh	Pienitz et al. 2003	1					0.3	
<i>Pinnularia brauniana</i>	Fresh	Pienitz et al. 2003	1				0.3		
<i>Pinnularia mesolepta</i>	Fresh	Fallu et al. 2000	1						
<i>Pinnularia microstauron</i>	Fresh	Fallu et al. 2000	1	16.5	12.0	9.2	0.6	0.3	
<i>Pinnularia nodosa</i>	Fresh	Fallu et al. 2000	1				0.3		
<i>Pinnularia problematica</i>	Fresh	Pienitz et al. 2003	1					1.7	
<i>Pinnularia subcapita var. subrostrata</i>	Fresh	Fallu et al. 2000	1			0.9			
<i>Pinnularia subgibba</i>	Fresh	Pienitz et al. 2003	1					5.2	
<i>Stauroneis neohyalina</i>	Fresh	Pienitz et al. 2003	1		5.3				
<i>Stauroneis phoenicenteron</i>	Fresh	Campeau et al. 1999	1					6.2	
<i>Staurosirella cf. leptostauron</i>	Oligohalobe	Pienitz et al. 2003	1					5.9	
<i>Epithemia adnata</i>	Fresh to brackish	Pienitz et al. 2003	2				1.7		
<i>Epithemia sorex</i>	Fresh to brackish	Werff 1974	2					1.4	

Core	Salinity	Source	Class	Sless	Sless	Sless	Sless	Sless	Sless
Depth				131	141	151	161	167	173
<i>Fragilaria pinnata</i>	Fresh to brackish	Campeau et al. 1999	2				10.5	12.1	
<i>Frustulia vulgaris</i>	Fresh to brackish	Lemieux 2001	2					2.4	
<i>Gomphenoma acuminatum</i>	Fresh to brackish	Lemieux 2001	2					0.7	
<i>Gomphenoma truncatum</i>	Fresh to brackish	Pienitz et al. 2003	2				0.3	0.7	
<i>Rhoicosphenia abbreviata</i>	Fresh to brackish	Pienitz et al. 2003	2				0.6	0.7	
<i>Sellaphora pupula</i>	Fresh to brackish	Pienitz et al. 2003	2						
<i>Stauroneis cf. anceps</i>	Fresh to brackish	Pienitz et al. 2003	2		38.7	32.3	0.9	1.0	
<i>Tabellaria floccosa</i>	Fresh and brackish	Lemieux 2001	2		1.3		5.7	6.6	
<i>Diploneis cf. vacillans</i>	Marine and brackish	Pienitz et al. 2003	3					0.7	
<i>Fragilaria virescens</i> var. <i>exigua</i>	Brackish	Campeau et al. 1999	3				3.7		
<i>Thalassiosira sp.</i>	Marine and brackish	Lemieux 2001	4			0.3			
Total				100	100	100	100	100	Barr en

Class Codes:
0- Unknown
1- Fresh Water
2-Fresh to brackish
3-Brackish
4-Brackish to Marine

SED Lake

Core	Salinity	Source	Class	SED	SED	SED	SED	SED	SED	SED
Depth				217	227	237	247	257	268	272
<i>Amphora sp.</i>	NA		0						0.4	
<i>Aulacoseira sp.</i>	NA		0			0.8	16.9		10.0	
<i>Chaetoceros sp.</i>	NA		0							11.1
<i>Cocconeis sp.</i>	NA		0						0.7	
<i>Caloneis sp.</i>	NA		0				0.3			
<i>Coscinodiscus sp.</i>	NA		0						5.6	
<i>Cymbella sp.</i>	NA		0			0.5			1.5	0.4
<i>Diploneis cf. modica</i>	NA	Campeau et al. 1999	0						0.4	
<i>Navicula sp.</i>	NA		0	0.3			1.2		1.5	0.4
<i>Neidium sp.</i>	NA		0				0.9			0.4
<i>Sellaphora sp.</i>	NA		0						0.4	
<i>Stauroneis sp.</i>	NA		0				0.3			0.4
<i>Surirella sp.</i>	NA		0						0.4	
<i>Tabellaria sp.</i>	NA		0						1.9	
<i>Aulacoseira cf. ambigua</i>	Fresh	Fallu et al. 2000	1			4.6				
<i>Aulacoseira distans</i>	Fresh	Fallu et al. 2000	1	9.1	69.8	0.8	30.1			3.1
<i>Aulacoseira lirata</i>	Oligohalobe	Lemieux 2001	1	17.3	18.7	21.5	16.9	62.8	18.2	36.3
<i>Aulacoseira perglabra</i>	Fresh	Fallu et al. 2000	1	45.9		24.8				
<i>Brachysira follis</i>	Fresh	Fallu et al. 2000	1						1.1	
<i>Brachysira styriaca</i>	Fresh	Pienitz et al. 2003	1			1.9				
<i>Cymbella delicatula</i>	Fresh	Pienitz et al. 2003	1				0.3	1.9		
<i>Cymbella microcephala</i>	Fresh	Fallu et al. 2000	1						0.4	
<i>Cymbella neocistula</i>	Fresh	Pienitz et al. 2003	1		2.3					
<i>Cymbella subcupidata</i>	Fresh	Fallu et al. 2000	1			0.3				
<i>Encyonema hebridicum</i>	Fresh	Pienitz et al. 2003	1						0.4	
<i>Encyonema neogracile</i>	Fresh	Pienitz et al. 2003	1	0.3		3.0	1.8		0.4	2.7
<i>Encyonema silesiacum</i>	Fresh	Pienitz et al. 2003	1				1.2		1.1	0.9
<i>Eunotia sp.</i>			1		1.0	4.9	2.4	0.9	3.3	0.4
<i>Eunotia diodon</i>	Oligohalobe	Pienitz et al. 2003	1			0.3				

Core	Salinity	Source	Class	SED	SED	SED	SED	SED	SED	SED
Depth				217	227	237	247	257	268	272
<i>Eunotia incisi</i>	Fresh	Fallu et al. 2000	1	2.3						
<i>Eunotia praerupta</i>	Fresh	Fallu et al. 2000	1			0.3				
<i>Eunotia rhomboidea</i>	Fresh	Fallu et al. 2000	1	0.3						
<i>Eunotia serra</i>	Fresh	Pienitz et al. 2003	1					1.6		
<i>Eunotia serra var. diadema</i>	Fresh	Fallu et al. 2000	1			0.3				
<i>Eunotia veneris</i>	Dystrophic	Lemieux 2001	1					4.4		
<i>Fragilaria constricta</i>	Fresh	Fallu et al. 2000	1		1.3	0.3		0.9	0.4	1.3
<i>Fragilaria lata</i>	Fresh	Fallu et al. 2000	1	0.3	1.3	1.1				
<i>Frustulia krammeri</i>	Olygohalobe	Pienitz et al. 2003	1				1.8	4.4		
<i>Frustulia saxinoma</i>	Olygohalobe	Pienitz et al. 2003	1	3.9	4.3	13.4	1.8		6.7	6.6
<i>Navicula papula sensu lato</i>	Fresh	Fallu et al. 2000	1				1.8			
<i>Neidium cf. ampliatum</i>	Fresh	Fallu et al. 2000	1			2.5				
<i>Neidium bisulcatum</i>	Fresh	Pienitz et al. 2003	1			0.5				
<i>Neidium iridis</i>	Fresh	Pienitz et al. 2003	1	0.7		0.5	0.9			
<i>Neidium saccoense</i>	Fresh	Pienitz et al. 2003	1							0.4
<i>Pinnularia sp.</i>		Lemieux 2001	1	2.6					2.2	
<i>Pinnularia biceps</i>	Fresh	Pienitz et al. 2003	1					0.9		1.3
<i>Pinnularia brauniana</i>	Fresh	Pienitz et al. 2003	1	0.3		7.9	2.7		0.7	
<i>Pinnularia mesolepta</i>	Fresh	Fallu et al. 2000	1	0.7		0.8				
<i>Pinnularia microstauron</i>	Fresh	Fallu et al. 2000	1	0.3		1.6	2.4		0.4	
<i>Pinnularia pluviformis</i>	Fresh	Pienitz et al. 2003	1					2.2		0.4
<i>Pinnularia problematica</i>	Fresh	Pienitz et al. 2003	1					0.9		0.4
<i>Pinnularia subgibba</i>	Fresh	Pienitz et al. 2003	1	2.0	1.0	1.4	2.1	1.6	0.7	3.1

Core	Salinity	Source	Class	SED	SED	SED	SED	SED	SED	SED
Depth				217	227	237	247	257	268	272
<i>Pinnularia cf. undulata</i>	Fresh	Lemieux 2001	1			3.0				
<i>Surirella cf. bifrons</i>	Fresh	Pienitz et al. 2003	1					0.9		
<i>Cocconeis placentula</i>	Fresh to brackish	Pienitz et al. 2003	2						0.7	
<i>Diatoma cf. vulgaris</i>	Oligohalobe	Campeau et al. 1999	2						0.4	
<i>Fragilaria brevistriata</i>	Oligohalobe	Campeau et al. 1999	2				0.3			
<i>Fragilaria construens</i>	Fresh to brackish	Campeau et al. 1999	2				7.2		0.4	
<i>Martyana martyi</i>	Fresh to brackish	Pienitz et al. 2003	2						0.4	
<i>Nitzshia sigma</i>	Fresh to brackish	Pienitz et al. 2003	2					2.5	6.3	0.4
<i>Pseudopstaurosira brevistriata</i>	Fresh to brackish	Pienitz et al. 2003	2						0.4	
<i>Rhoicosphenia abbreviata</i>	Fresh to brackish	Pienitz et al. 2003	2			0.3				
<i>Sellaphora pupula</i>	Fresh to brackish	Pienitz et al. 2003	2				0.3			
<i>Stauroneis cf. anceps</i>	Fresh to brackish	Pienitz et al. 2003	2				1.8	2.5	0.4	
<i>Tabellaria floccosa</i>	Fresh to brackish	Lemieux 2001	2	13.7	0.3	2.7	3.6	11.6	1.9	0.4
<i>Coscinodiscus cf. curvalatus</i>	Brackish	Lemieux 2001	3							0.4
<i>Fragilaria virescens var. exigua</i>	Brackish	Campeau et al. 1999	3				0.6			
<i>Grammetaphora cf. oceanica</i>	Brackish	Pienitz et al. 2003	3						0.7	
<i>Psammodictyon panduriforme var. delicatulum</i>	Brackish	Pienitz et al. 2003	3						0.4	
<i>Tabellaria fasciculata</i>	Mesohalobe	Pienitz et al. 2003	3						0.7	0.4
<i>Thalassiosira proschkiniae</i>	Mesohalobe	Pienitz et al. 2003	3						7.8	
<i>Bacillaria socialis</i>	Marine to brackish	Pienitz et al. 2003	4						1.5	0.4
<i>Cocconeis cf. californica</i>	Polyhalobe	Pienitz et al. 2003	4						0.4	

Core	Salinity	Source	Class	SED	SED	SED	SED	SED	SED	SED
Depth				217	227	237	247	257	268	272
<i>Cocconeis costata</i> <i>var. pacifica</i>	Meso- polyhalobe	Pienitz et al. 2003	4							0.4
<i>Cocconeis</i> <i>scutellum</i>	Mesohalobe to Polyhalobe	Pienitz et al. 2003	4							2.2
<i>Coscinodiscus cf.</i> <i>radiatus</i>	Polyhalobe	Pienitz et al. 2003	4						4.8	0.4
<i>Diploneis</i> <i>bomboides</i>	Brackish to marine	Pienitz et al. 2003	4							0.4
<i>Fallacia litoricola</i>	Meso- polyhalobe	Pienitz et al. 2003	4							0.4
<i>Fragilariopsis</i> <i>oceanica</i>	Brackish to marine	Pienitz et al. 2003	4						5.6	
<i>Navicula</i> <i>digitoradiata</i>	Brackish to marine	Pienitz et al. 2003	4						2.6	1.3
<i>Nitzschia cf.</i> <i>liebetruthii</i>	Brackish to marine	Pienitz et al. 2003	4							0.4
<i>Rhabdonema</i> <i>arcuatum</i>	Euhalobe	Werff 1974	4							1.3
<i>Surirella fatuosa</i>	Brackish to marine	Pienitz et al. 2003	4							0.4
<i>Thalassionema</i> <i>nitzschoides</i>	Mesohalobe to polyhalobe	Pienitz et al. 2003	4						0.4	1.8
<i>Thalassiosira sp.</i>	Brackish to marine	Lemieux 2001	4						4.8	12.4
<i>Thalassiosira</i> <i>eccentrica</i>	Polyhalobe	Pienitz et al. 2003	4				0.3			0.4
<i>Thalassiosira</i> <i>hyalina</i>	Polyhalobe	Pienitz et al. 2003	4							0.4
<i>Thalassiosira</i> <i>pacifica</i>	Polyhalobe	Pienitz et al. 2003	4						0.7	4.4
<i>Thalassiosira cf.</i> <i>tenera</i>	Marine	Pienitz et al. 2003	4							0.9
Total				100	100	100	100	100	100	100

Class Codes: 0- Unknown
1- Fresh
Water
2-Fresh to
brackish
3-Brackish
4-Brackish to
Marine

SB Bog

Core	Salinity	Source	Class	SBB	SBB	SBB	SBB	SBB	SBB	SBB	SBB	SBB	SBB	SBB	SBB	SBB	SBB
Depth				120	145	170	175	185	190	200	205	215	220	225	230	240	260
<i>Acnantes sp.</i>	NA		0			0.4											
<i>Amphora sp.</i>	NA		0				0.6										
<i>Aulacoseira sp.</i>	NA		0							2.2	3.7					5.0	
<i>Brachysira sp.</i>	NA		0	0.6													
<i>Caloneis sp.</i>	NA		0				1.2										
<i>Coscinodiscus sp.</i>	NA		0			0.4				4.3	1.5		4.3				
<i>Cyclotella sp.</i>	NA		0								0.7						
<i>Cymbella sp.</i>	NA		0	0.3		3.0	1.6										
<i>Diatoma sp.</i>	NA		0							2.2	0.7						
<i>Diploneis sp.</i>	NA		0				1.2				0.7						
<i>Gyrosigma sp.</i>	NA		0			1.7											
<i>Melosira cf. roeseana</i>	Atmophytic	Lemieux 2001	0								1.5						
<i>Navicula sp.</i>	NA		0	0.3	1.4		2.2										
<i>Neidium sp.</i>	NA		0				0.3										
<i>Psammodictyon sp.</i>	NA		0				0.3										
<i>Stauroneis sp.</i>	NA		0	0.8							0.7						
<i>Surirella sp.</i>	NA		0				3.7										
<i>Synedra sp.</i>	NA		0								0.7						
<i>Actinella punctata</i>	Dystrophic	Pienitz et al. 2003	1	0.8	0.3												
<i>Acnantes calcar</i>	Oligohalobe	Campeau et al. 1999	1				0.6										
<i>Aulacoseira distans</i>	Fresh	Fallu et al. 2000	1	12.9	15.0	6.9				17.4	2.2				1.7		

Core	Salinity	Source	Class	SBB	SBB	SBB	SBB	SBB	SBB	SBB	SBB	SBB	SBB	SBB	SBB	SBB	SBB
Depth				120	145	170	175	185	190	200	205	215	220	225	230	240	260
<i>Diploneis papula</i>	Euhalobe	Werff 1974	4					9.1									
<i>Diploneis smithii</i>	Polyhalobe	Campeau et al. 1999	4			5.6											
<i>Opephora marina</i>	Polyhalobe	Campeau et al. 1999	4			0.4											
<i>Paralia sulcata</i>	Polyhalobe	Campeau et al. 1999	4								1.5				1.7		
<i>Plagiogramma staurophorum</i>	Polyhalobe	Pienitz et al. 2003	4			0.4											
<i>Rhabdonema arcuatum</i>	Euhalobe	Werff 1974	4					9.1		15.2	13.2						
<i>Rhabdonema minutum</i>	Marine	Werff 1974	4								9.6						
<i>Thalassiosira sp.</i>	Brackish to marine	Lemieux 2001	4							17.4	8.1		91.3		33.9	85.0	
<i>Thalassiosira eccentrica</i>	Polyhalobe	Pienitz et al. 2003	4								27.2						
<i>Thalassiosira pacifica</i>	Polyhalobe	Pienitz et al. 2003	4													5.0	
<i>Trachyneis aspera</i>	Marine	Pienitz et al. 2003	4					45.5			0.7						

Core	Salinity	Source	Class	SBB	SBB	SBB	SBB	SBB	SBB	SBB	SBB	SBB	SBB	SBB	SBB	SBB	SBB
Depth				120	145	170	175	185	190	200	205	215	220	225	230	240	260
<i>Tryblionella coarctata</i>	Marine	Pienitz et al. 2003	4					27.3									
Total				100	100	100	100	100	0	100	100	0	100	0	100	100	0

SH Lake

Core	Salinity	Source	Class	SH2	SH2	SH2	SH2	SH2	SH2	SH2	SH2
Depth				44	53	64	69	73	88	108	123
<i>Acnantes sp.</i>	NA		0		2.7	1.6					
<i>Amphora sp.</i>	NA		0								0.3
<i>Cocconeis sp.</i>	NA		0						0.3		
<i>Coscinodiscus sp.</i>	NA		0						0.3	0.3	
<i>Cyclotella sp.</i>	NA		0					0.9			
<i>Diploneis sp.</i>	NA		0					0.9	0.3	1.5	
<i>Gomphenoma sp.</i>	NA		0						0.3		
<i>Gyrosigma sp.</i>	NA		0				3.9	0.3	6.8	0.3	
<i>Melosira cf. roeseana</i>	Atmophytic	Lemieux 2001	0								
<i>Navicula sp.</i>	NA		0				6.9	0.3	0.6		
<i>Neidium sp.</i>	NA		0			1.3					
<i>Stauroneis sp.</i>	NA		0	0.3	0.7						
<i>Surirella sp.</i>	NA		0						0.3		
<i>Surirella brightwelli var. baltica</i>	NA		0				0.7				
<i>Tryblionella marginulata var. subconstricta</i>	Brackish	Pienitz et al. 2003	0						0.3		
<i>Actinella punctata</i>	Dystrophic	Pienitz et al. 2003	1	0.6	1.7	0.6					
<i>Aulacoseira distans</i>	Fresh	Fallu et al. 2000	1	12.5	19.1	7.8			0.3		
<i>Aulacoseira lirata</i>	Oligohalobe	Lemieux 2001	1	20.1	2.0	28.1	2.9		18.9	0.3	
<i>Aulacoseira perglabra</i>	Fresh	Fallu et al. 2000	1			8.4					
<i>Cymbella gaeumannii</i>	Fresh	Fallu et al. 2000	1		0.3						
<i>Encyonema neogratile</i>	Fresh	Pienitz et al. 2003	1	0.6	2.0	0.3					
<i>Encyonema silesiacum</i>	Fresh	Pienitz et al. 2003	1	0.6		2.5	0.7				
<i>Eunotia sp.</i>			1	6.0	5.4	9.7			0.3		
<i>Eunotia bidentula</i>	Fresh	Fallu et al. 2000	1	7.5	24.4						
<i>Eunotia flexuosa</i>	Fresh	Fallu et al. 2000	1			0.3					
<i>Eunotia hemicyclus</i>	Fresh	Fallu et al. 2000	1			1.3					

Core	Salinity	Source	Class	SH2	SH2	SH2	SH2	SH2	SH2	SH2	SH2
Depth				44	53	64	69	73	88	108	123
<i>Eunotia lapponica</i>	Oligohalobe	Pienitz et al. 2003	1						1.2		
<i>Eunotia serra</i>	Fresh	Pienitz et al. 2003	1	3.1	0.7	1.3			0.3		
<i>Eunotia cf. serra</i>	Fresh	Pienitz et al. 2003	1	1.9							
<i>Fragilaria constricta</i>	Fresh	Fallu et al. 2000	1	0.3	1.7						
<i>Fragilaria construens var. exigua</i>	Fresh	Fallu et al. 2000	1			0.6	0.3				
<i>Fragilaria lata</i>	Fresh	Fallu et al. 2000	1	4.7	13.4	11.3					
<i>Frustulia krammeri</i>	Olygohalobe	Pienitz et al. 2003	1	0.3							
<i>Frustulia saxinoma</i>	Olygohalobe	Pienitz et al. 2003	1	24.1	16.4		0.7		0.6		
<i>Neidium cf. ampliatum</i>	Fresh	Fallu et al. 2000	1	0.3						0.6	
<i>Neidium densestriatum</i>	Fresh	Fallu et al. 2000	1			0.3					
<i>Neidium iridis</i>	Fresh	Pienitz et al. 2003	1	2.8		1.6			0.3	0.6	
<i>Pinnularia sp.</i>		Lemieux 2001	1	0.6	0.3	1.6					
<i>Pinnularia brauniana</i>	Fresh	Pienitz et al. 2003	1		1.0	1.3			0.3		
<i>Pinnularia mesolepta</i>	Fresh	Fallu et al. 2000	1	0.3							
<i>Pinnularia microstauron</i>	Fresh	Fallu et al. 2000	1	0.6							
<i>Pinnularia subgibba</i>	Fresh	Pienitz et al. 2003	1		0.3	2.2			2.1		
<i>Pinnularia cf. subgibba</i>	Fresh	Pienitz et al. 2003	1	0.9							
<i>Pinnularia cf. undulata</i>	Fresh	Lemieux 2001	1								
<i>Semiorbus hemicyclus</i>	Oligohalobe	Pienitz et al. 2003	1	0.3	1.3						
<i>Stephanodiscus cf. medius</i>	Fresh	Pienitz et al. 2003	1						0.6		
<i>Surirella cf. bifrons</i>	Fresh	Pienitz et al. 2003	1						0.3		
<i>Amphora ovalis</i>	Fresh to brackish	Pienitz et al. 2003	2					0.3			

Core	Salinity	Source	Class	SH2	SH2	SH2	SH2	SH2	SH2	SH2	SH2
Depth				44	53	64	69	73	88	108	123
<i>Cavinula cocconeiformis</i>	Fresh to brackish	Pienitz et al. 2003	2								0.3
<i>Cocconeis cf. placentula</i>	Fresh to brackish	Pienitz et al. 2003	2				9.8				
<i>Fragilaria brevistriata</i>	Oligohalobe	Campeau et al. 1999	2			0.3					
<i>Fragilaria pinnata</i>	Fresh to brackish	Campeau et al. 1999	2			9.7	0.3				
<i>Nitzshia sigma</i>	Fresh to brackish	Pienitz et al. 2003	2				4.6	3.5	8.9	1.5	
<i>Stauroneis cf. anceps</i>	Fresh to brackish	Pienitz et al. 2003	2	0.3		0.3				0.3	
<i>Stenopterobia cf. curvula</i>	Fresh to brackish	Pienitz et al. 2003	2				0.7				
<i>Tabellaria floccosa</i>	Fresh to brackish	Lemieux 2001	2	11.0	6.7	3.1		0.3	1.2		
<i>Amphora cf. acutiuscula</i>	Mesohalobe	Campeau et al. 1999	3				1.3				
<i>Diatoma cf. moniliformis</i>	Mesohalobe	Campeau et al. 1999	3						0.3		
<i>Fragilaria virescens var. exigua</i>	Brackish	Campeau et al. 1999	3			4.4	0.3				
<i>Gyrosigma balticum</i>	Marine littoral and brackish	Pienitz et al. 2003	3						3.0		
<i>Mastogloia pumila</i>	Brackish	Pienitz et al. 2003	3				0.3				
<i>Melosira nummuloides</i>	Brackish	Pienitz et al. 2003	3						0.3		
<i>Navicula peregrina</i>	Mesohalobe	Campeau et al. 1999	3				0.3				
<i>Opephora olensii</i>	Mesohalobe	Campeau et al. 1999	3				0.3				
<i>Caloneis cf. liber</i>	Marine littoral	Pienitz et al. 2003	4							0.9	
<i>Cocconeis cf. californica</i>	Polyhalobe	Pienitz et al. 2003	4			0.3					
<i>Cocconeis costata var. pacifica</i>	Meso-polyhalobe	Pienitz et al. 2003	4				0.3				
<i>Cocconeis cf. costata</i>	Meso-polyhalobe	Pienitz et al. 2003	4				11.4	0.6	0.3		

Core	Salinity	Source	Class	SH2	SH2	SH2	SH2	SH2	SH2	SH2	SH2
Depth				44	53	64	69	73	88	108	123
<i>Cocconeis scutellum</i>	Mesohalobe to Polyhalobe	Pienitz et al. 2003	4				40.8	0.9	0.6	0.9	0.3
<i>Dictyocha fibula</i>	Marine	Pienitz et al. 2003	4						0.3		
<i>Fallacia litoricola</i>	meso-polyhalobe	Pienitz et al. 2003	4				0.3				
<i>Fragilariopsis oceanica</i>	Marine and brackish	Pienitz et al. 2003	4					0.9			
<i>Navicula digitoradiata</i>	Marine and brackish	Pienitz et al. 2003	4						0.3		
<i>Paralia sulcata</i>	Polyhalobe	Campeau et al. 1999	4				12.7	87.9	49.7	92.0	98.1
<i>Plagiogramma staurophorum</i>	Polyhalobe	Pienitz et al. 2003	4				0.3	3.2	0.9	0.6	1.1
<i>Rhabdonema arcuatum</i>	Euhalobe	Werff 1974	4						0.3		
<i>Rhabdonema minutum</i>	Marine	Werff 1974	4						0.3		
<i>Thalassionema nitzschioides</i>	Mesohalobe to polyhalobe	Pienitz et al. 2003	4					0.6			
<i>Thalassiosira sp.</i>	Marine and Brackish	Lemieux 2001	4					0.6		0.3	0.6
<i>Thalassiosira eccentrica</i>	Polyhalobe	Pienitz et al. 2003	4				0.3			0.3	
<i>Tryblionella coarctata</i>	Marine	Pienitz et al. 2003	4					0.3			
Total				100	100	100	100	100	100	100	100

Class Codes: 0- Unknown
1- Fresh Water
2-Fresh to brackish
3-Brackish
4-Brackish to Marine