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Authors: Bhiry, Najat, Marguerie, Dominique, and Lofthouse, Susan

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Paleoenvironmental reconstruction and timeline of a Dorset-Thule settlement at Quaqtaq (Nunavik, Canada)

Najat Bhiry[1,*], Dominique Marguerie[2], and Susan Lofthouse[3]

[1]Centre d'études nordiques and Department of Geography, Laval University, Québec, Québec, G1V 0A6, Canada
[2]CNRS, UMR6553 ECOBIO, University of Rennes 1, Beaulieu, 35042 Rennes cedex, France
[3]Avataq Cultural Institute, 360-4150, Ste-Catherine O., Westmount, Québec, H3Z 2Y5, Canada
[*]Corresponding author email: najat.bhiry@cen.ulaval.ca

ABSTRACT

A geoarchaeological and paleobotanical study of a Paleoeskimo and Neoeskimo site was undertaken in order to reconstruct site-formation processes. The study site JfEl-10 is located on Igloo Island, in Diana Bay, on the southern shore of Hudson Strait. It contains a peat-mineral deposit situated between two successive beach crests, close to a small marsh. Samples from the edge of the site, which consists of a remarkable section of stratigraphy 60 cm thick that contains alternating brown organic beds and light-colored sand beds, were examined in the laboratory. Macrofossil data and pollen data were used to reconstruct the local and regional vegetation and to determine climatic changes over the past 1200 years. The geoarchaeological study includes the stratigraphy and the sedimentology of archaeological sediments. The evolution of the site followed three successive environmental phases, and the site was home to two distinct cultures. The first phase (from ca. 1200 to ca. 950 cal. yr B.P.) was characterized by cold and mesic conditions and the Dorset occupation. In the second phase, conditions became more humid beginning ca. 950 cal. yr B.P. and lasted for approximately 450 years. This period is marked by the arrival of Thule Inuit, who hunted marine mammals in the vicinity. Zooarchaeological information indicated a fall/winter occupation during the Thule Inuit period. The third phase corresponds with the onset of the Little Ice Age (A.D. 1500–1850) and associated cooling. During this time, the Thule Inuit abandoned the site. If the increased cooling caused an earlier freeze-up of Diana Bay, this may have prevented the movement of walrus to their haul-out island during fall. Additionally, the faster accumulation of thick ice would have limited the hunting of seals through their breathing holes.

INTRODUCTION

The landscapes and ecosystems of the coastal zones of the Arctic regions have been shaped primarily by Quaternary geology (e.g., land emersion) but also by climate change (e.g., Péwé, 1975; Gray et al., 1980; Lauriol and Gray, 1987; Alley et al., 1997; Overpeck et al., 1997; Bennike and Weidick, 1998; Gray, 2001; Kaplan et al., 2003). These changes had a significant impact on the habitability of the land, which in turn influenced the choice of sites for human occupation. Several archaeologists have hypothesized that climate fluctuations during the Late Holocene (from 3500 cal. yr B.P.) (^{14}C yr B.P.) influenced population dynamics and behavioral decisions, largely because of their direct impact on environmental conditions and the availability of resources (e.g., McGhee, 1969/1970; Dekin, 1972; Plumet, 1974; Matthews, 1975; Schledermann, 1976; Barry et al, 1977; Plumet and Gangloff, 1987; Arge et al., 2005; Mudie et al., 2005; Friesen, 2010; Woollett, 2010). Any modification of biophysical

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factors can have a rapid effect on living conditions, whether at the local or regional level. While a few studies have conducted regional investigations of this relationship between human occupation and environmental change in the High Arctic (Finkelstein et al., 2009; Dyke et al., 2011), a number of recent studies have indicated a positive correlation at the local and regional level in the Low Arctic of eastern Canada (Fitzhugh, 1972; Desrosiers et al., 2010; Lemieux et al., 2011; Roy et al., 2012).

The Ungava Peninsula region is located in the extreme north of Quebec (Canadian Low Arctic) between Hudson Bay in the west and Ungava Bay in the east (Fig. 1, part a). It is a region that offers a unique vantage point on past climate and environmental changes. In addition, there have been significant changes in human occupation and activity in the region over the last 4000 years (Avataq Cultural Institute, 2012). Specifically, Pre-Dorset (2500–500 B.C.), Dorset (500 B.C.–A.D. 1100), and Thule Inuit (after A.D. 1200) occupations have been recorded at over 4000 sites in the region (e.g., Gendron and Pinard, 2001; Arsenault and Gendron, 2007; Pinard and Gendron, 2009). For the most part, these sites are located along the coast and on islands.

The extent of overlap between Dorset and Thule Inuit occupations in the same geographic area has been debated. In fact, while archaeological studies such as McGhee (2000) and Friesen (2004) proposed a temporal overlap between the Dorset and the Thule people, other scholars (e.g., Park, 1993, 2000; Pinard and Gendron, 2009) have suggested that the Dorset people had disappeared from the eastern Arctic prior to the arrival of the Thule. The latter scenario seems to be supported by a recent study involving paleogenetic data (Raghavan et al., 2014), which identified two separate migration pulses from Siberia across the New World Arctic: the initial Paleoeskimo movement, followed later by a separate Thule migration. The results showed no evidence for genetic admixture between the two populations. The margin for overlap between Dorset and Thule Inuit occupations has been reduced in recent years, through a revision of radiocarbon dates (McGhee, 2000, 2009; Friesen and Arnold, 2008; Morrison, 2009) that places the initial Thule migration during the 13th century—two centuries later than previous interpretations suggested.

Site JfEl-10 is situated in Diana Bay near Quaqtaq, in the northeastern part of the Ungava Peninsula. Diana Bay is known as *Tuvaaluk* in Inuktitut, which means "the big expanse of ice" (Dorais, 1997): this name derives from the bay's early freeze-up and late thaw. As is frequently the case at Thule sites in Nunavik, JfEl-10 contains a mixture of Dorset and Thule archaeological remains (Avataq Cultural Institute, 2003). Archaeological research in Diana Bay, in northeastern Ungava peninsula, was undertaken during the 1970s. Radiocarbon dating of JfEl-10 and nearby Dorset sites indicated an overlap of Dorset and Thule occupations in this area (Plumet, 1979, 1989, 1994). More recent archaeological investigations, undertaken within the same context as this study, resulted in the redating of JfEl-10. The newer dates indicate a Thule Inuit presence in the area that postdates the Dorset occupation (Lofthouse, 2003, 2007; Pinard and Gendron, 2007) (Table 1).

Initially, JfEl-10 on Illutalialuk (Igloo Island) in the southeastern corner of Diana Bay, was described as an exclusively Thule occupation and yielded the very early date of 747 cal. yr B.P. (derived from 810 ± 80 B.P. in Plumet, 1979, 1994). A later date of 501 cal. yr B.P. (derived from 470 ± 90 B.P. in Plumet, 1994) was retrieved from JfEl-4 on nearby Diana Island. This date was attributed to a Dorset presence, while the Thule architectural traits, including entrance tunnel and architectural whale bone, were suggested to have been applied by Dorset individuals influenced by their Thule neighbors (Plumet, 1994). In 2002, JfEl-10 was revisited by researchers who found a mixed Dorset and Thule artifact assemblage through their excavations, indicating that the early date was from a compromised context (Lofthouse, 2003, 2007; Pinard and Gendron, 2009). While JfEl-4 was not revisited, the more parsimonious explanation for the mixed architectural traits is that the JfEl-4 site, like JfEl-10, represents a Thule Inuit reuse of a Dorset site.

The overall objective of this research was to document the evolution of the paleoenvironmental conditions at site JfE1-10 in the periglacial zone. Specific objectives were (1) to identify the sedimentary and postsedimentary processes that contributed to the formation of the archaeological sediment layers, and (2) to document the vegetation dynamic at the local and regional scales in the

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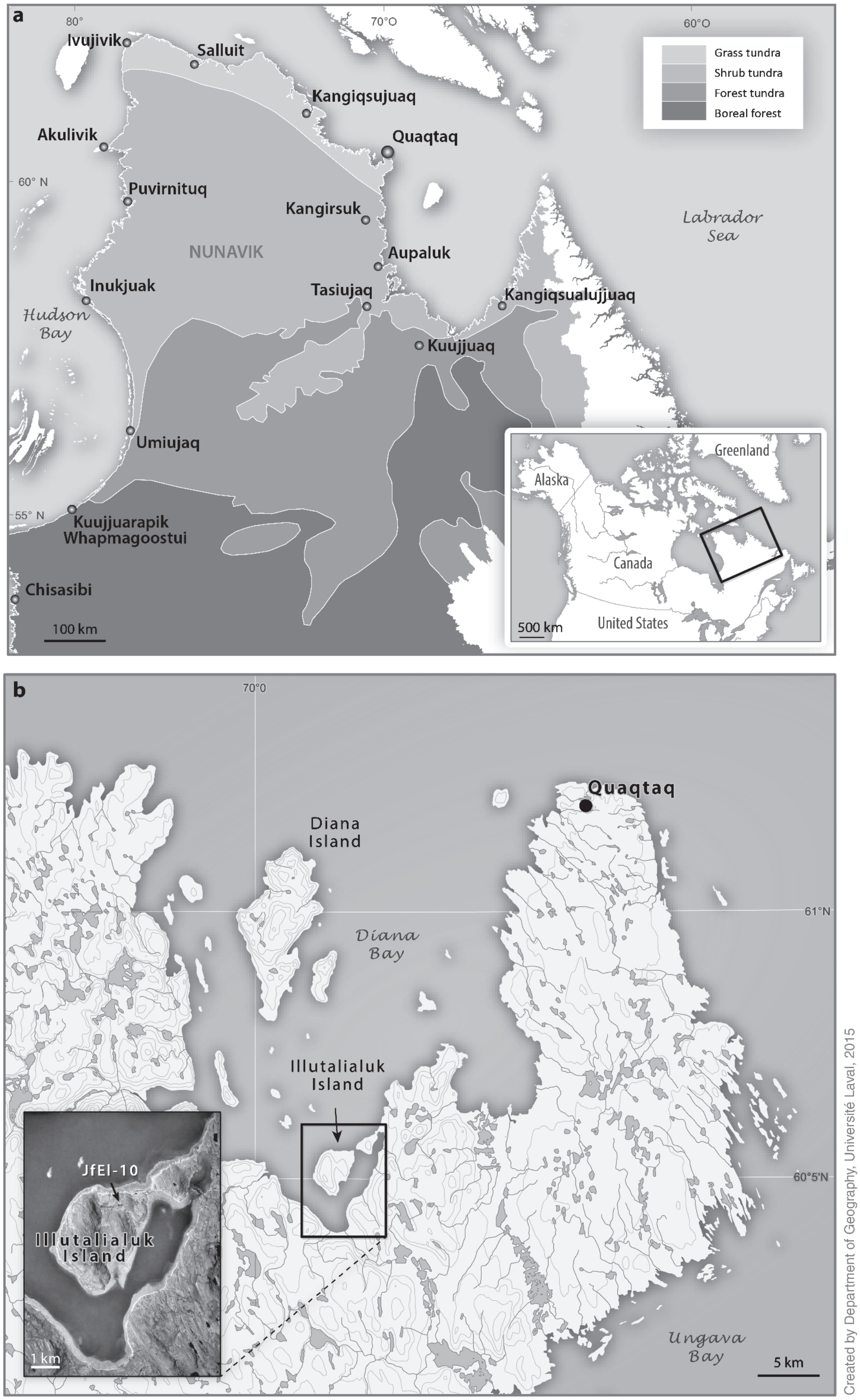

FIGURE 1. (a) Location of the study area and vegetation zones in Nunavik; and (b) location of Illutalialuk in Diana Bay and JfE1-10 on Illutalialuk.

region surrounding the study site. Analysis of the data will help to determine climate changes at the site before, during, and after the various human occupations.

Physical Setting

Study site JfE1-10 is situated in Diana Bay, about 35 km south of Quaqtaq village (61°02′00″N;

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TABLE 1

Archaeological radiocarbon dates and calibrated age of JfEl-10 site on Illutalialuk, Nunavik. Str. = Structure.

Sample location	Laboratory number	Age (^{14}C yr B.P.)	Age (cal. yr B.P.) (2 σ)	Midpoint calibrated age (cal. yr B.P.)	Age (cal.yr A.D.–B.C.) (2 σ)	Material dated
Str. D kitchen alcove	GIF 4209	810 ± 80	652–920	747	A.D. 1030–1298	Charcoal
Str. H midden	BGS 2447	480 ± 70	319–649	520	A.D. 1301–1631	Wood
Str. H midden	BGS 2448	350 ± 90	0–540	390	A.D. 1410–1950	Charcoal
Str. E midden	BGS 2449	700 ± 70	540–742	650	A.D. 1208–1410	Charcoal
Str. E interior	BGS 2450	575 ± 40	527–652	600	A.D. 1298–1423	Charcoal
Str. D midden	BGS 2451	670 ± 40	555–683	640	A.D. 1267–1395	Charcoal
Str. D kitchen alcove	BGS 2452	450 ± 45	327–547	500	A.D. 1403–1623	Charcoal and wood

Str. = Structure.

69°37′00″W) on the south shore of Hudson Strait in the northeast of the Ungava Peninsula (northern Quebec, Canada) (Fig 1, part a). More precisely, the archaeological site is located in a valley on Illutalialuk, otherwise known as "Igloo Island" (Fig. 1, part b). Diana Bay contains many islands, the majority of which are oriented north-south. In terms of physiogeography, this bay is part of the Ungava Bay coast, which consists of a narrow belt of hills and cuestas corresponding to the circum-Ungava geosyncline (Gray and Lauriol, 1985). Deglaciation of the region occurred between 7000 and 7500 yr B.P. (Gangloff et al., 1976). Postglacial sea levels on the islands in Diana Bay varied between 131 and 138 m, while on the coasts sea levels were less elevated (between 119 and 127 m). The emersion curves indicate an isostatic uplift of around 40–50 m from 6500 to 2000 yr B.P. After 2000 yr B.P., the isostatic uplift was less than 7 m (Gray et al., 1993).

The region is located in the zone of continuous permafrost (Allard and Séguin, 1987). The prevailing climate is a cold and dry Arctic climate. Annual precipitation totals 380 mm, with 45%–50% falling as snow (Environment Canada, 2013). The south coast of Hudson Strait is part of the northern sector of the Arctic tundra (Richard, 1981; Payette, 1983, 1993; Blondeau, 1990; Blondeau and Cayouette, 2002) (Fig. 1, part a). This vegetation zone can be subdivided into two biogeographic sectors: (1) an herbaceous tundra on the high plateaus of Hudson Strait that includes Arctic species of sedges, grasses, mosses, and lichens, and (2) a shrub-tundra, principally in the valleys, which contains shrub-species such as *Alnus crispa* and *Betula glandulosa* and is dominated by willow species such as *Salix glauca* and *Salix planifolia* (Payette, 1993; Blondeau and Cayouette, 2002; Blondeau and Roy, 2004).

Illutalialuk is now linked to the mainland by a tombolo (Fig. 1, part b). Several ponds lie along the ridge upstream (to the west), which are now in the path of peat development. Site JfE1-10 lies on a shelf between two successive beach ridges rising between 15 and 20 m above sea level and 500 m from the shore, in a valley oriented toward the northwest. The site is composed of three oval semisubterranean structures (D, E, and H), each of which has an entrance tunnel, along with five more structurally ambiguous features (A, B C, F, and G). The latter were initially identified as semisubterranean houses (Plumet, 1979), but the 2002 investigations found this distinction less clear. At least some of these may have been Dorset structures, where sod was removed for the construction of Structures D, E, and H: however, no excavations were undertaken to test this interpretation (Lofthouse, 2003, 2007). The three semisubterranean structures were selected (D, E, and H) for archaeological investigation (Fig. 2, part a). Many artifacts were recovered from Structures D and E, but melting permafrost compromised the excavation of Structure H's interior (Avataq Cultural Institute, 2003). However, it was possible to excavate a small midden located alongside Structure H. All three semisubterranean houses yielded a mixture of Dorset and Thule Inuit artifacts (Avataq Cultural Institute, 2003; Lofthouse, 2003, 2007). Structure H is bordered to the east by a strip of alternating clear sand beds and brown organic beds, with a total thickness of approximately 60 cm (Fig. 2, part b). This natural deposit is characterized by well-arranged beds that accumulated

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in a continuous and orderly manner (Fig. 3, part a). When we dug 50 cm through this section we discovered that the beds continue deep inside without interruption (Fig. 3, part b). This peat-mineral accumulation is of particular interest because it can be used to reconstruct the paleoenvironmental conditions of the site using paleoecological and sedimentological methods.

Archaeological research at JfEI-l0 was conducted during the 1970s (Salaün, 1975; Plumet, 1979, 1994) and during the summer of 2002 by a team from the Avataq Cultural Institute, Laval University, and McGill University that was sponsored by the Community-University Research Alliance (CURA) "From Tuniit to Inuit" project (Avataq Cultural Institute, 2003; Lofthouse, 2003, 2007). The study presented in this paper was also conducted within the framework of that CURA project.

Methods

During the 2002 excavation, a section was dug into the east side of Structure H. The stratigraphy was examined and documented. Samples from the light-colored sand layers were collected for sedimentological analysis (i.e., grain size and the morphoscopy and exoscopy of quartz), while brown organic layers were sampled for paleoecological analysis. Macrofossil and pollen analyses were performed on each organic layer. Five cores were extracted from the nearby pond in order to date peat inception for comparison to peat accumulation in Structure H.

Grain Size, Morphoscopy, and Exoscopy of Quartz Grains

Grain size was obtained using a sedigraph (<63 μm), a sedimentation tube (63–1000 μm), and a sieve column (>1000 μm). Data were integrated using the Particle Sizing System 3.1 (PSS) software. Three parameters were calculated using the moment statistical methods (McManus, 1988): mean size (Ms), standard deviation or sorting coefficient (Sd), and skewness (Sk). Characteristics of the sedimentary environment were deduced from the relationship between mean size and standard deviation, and from the relationship between mean size and skewness (Stewart, 1958). Morphoscopy of the quartz grains was conducted using a stereomicroscope at 4× to 16× magnification, while the exoscopy of the quartz grains required a scanning electron microscope (S.E.M.).

Macrofossil Analysis

The macrofossil content of each layer (organic or mineral) was analyzed. For the layers that were richer in peat, more than one level was analyzed: four sublevels of L12 and two sublevels of L4 (see Fig. 2, part b). Macrofossil analysis was conducted following the protocol outlined by Bhiry and Filion (2001). The sediment was treated with a weak 5% aqueous KOH solution and boiled for a few minutes to deflocculate. The material was then wet-screened through a series of sieves (250, 180, and 63 μm mesh). Macrofossils were identified under stereomicroscope at 4× to 40× magnification. References used in identifying plant remains were Montgomery (1977), Crum and Anderson (1979–1980), Ireland (1982), and the collection of the Centre d'études nordiques of Laval University (Québec City, Canada).

Pollen Analysis

Pollen and spore analyses were carried out on the brown organic layers. For each layer, 3 cm^3 of sediment were processed following the procedure in Faegri and Iversen (1989) and Lavoie (2001). First, the sediment was subjected to chemical treatment with 10% KOH, HF, HCl, and acetolysis. A *Eucalyptus globulus* pollen suspension of known volume and concentration was then added to each sample before preparation in order to calculate pollen concentration (grains per cm^3) (Benninghoff, 1962).

The pollen grain sum for terrestrial vascular plants (pollen sum) varied from 330 to 970. Pollen and spore identification followed Richard (1970), McAndrews et al. (1973), and Moore et al. (1991). The pollen collections of the Centre d'études nordiques and the Archaeosciences Laboratory of University of Rennes 1 were used as references for the identification of problematic specimens. Pollen and macrofossil diagrams were drawn using the Palaeo Data Plotter (Juggins, 2002).

Radiocarbon Dating

Ten samples were dated by the conventional radiocarbon method at the Centre d'études nordiques

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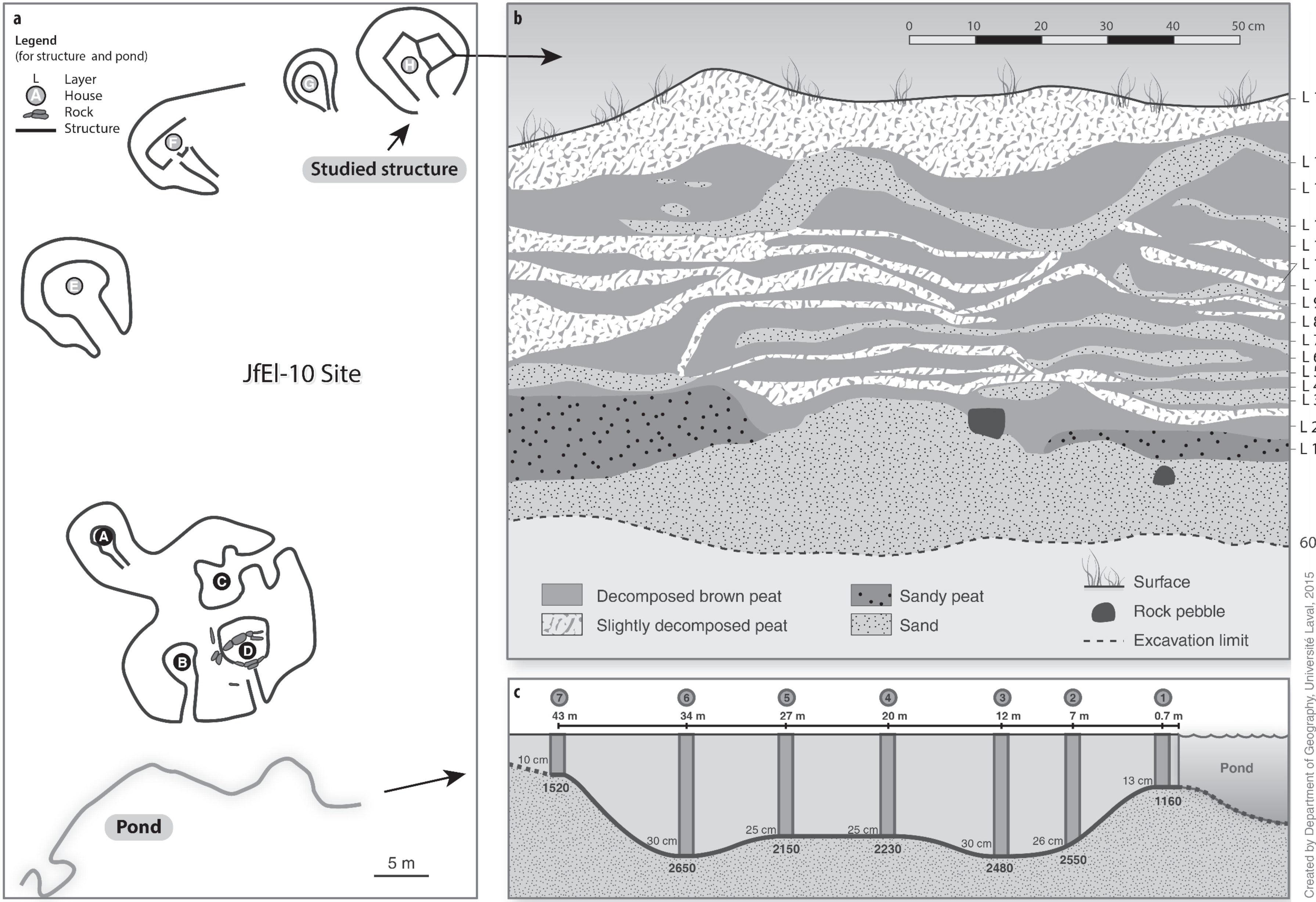

FIGURE 2. (a) Map of JfE1-10; (b) stratigraphy of peat-mineral accumulation on the eastern edge of Structure H (modified from Avataq Cultural Institute, 2004); and (c) peat development along the ridge upstream into the southern pond of the site.

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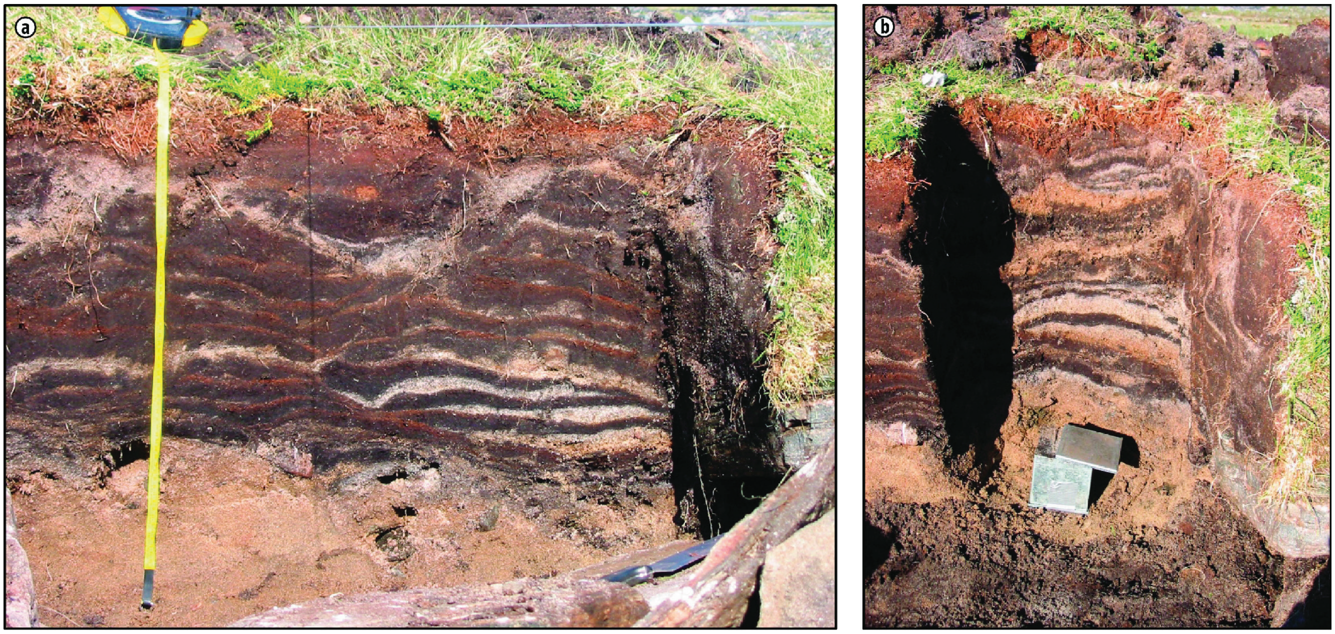

FIGURE 3. (a) Natural succession of organic and mineral layers; and (b) section excavated showing the continuity of layers, Structure H, Site JfE1-10, Diana Bay, Nunavik (Canada).

Laboratory at Laval University. These included one sample from the bottom layer (L1) and one sample from L12 of the studied section, one sample from a tree stump found inside of Structure H, and seven samples from cores extracted from the nearby pond (Fig. 2, part c). Dates were calibrated using the CALIB 6.0.1. program (Stuiver et al., 2011). Calibrated ages (cal. yr B.P.) were rounded to the nearest decade.

Results and Interpretation

Stratigraphic and Chronological Data

When excavated, the eastern edge of Structure H revealed a 60-cm-thick sedimentary section composed of alternating sand and organic layers (Fig. 2, part b). These layers are subhorizontally undulated and some of them are discontinuous. The bottom layer (L1) is about 6 cm thick and consists of mixed sand and peat material. The thickness of the sandy layers (L3, L5, L7, L9, L11, and L13) ranges from 1 cm (L7 and L 9) to 6 cm (L13). Organic layers consist of decomposed dark brown peat or slightly decomposed brown peat. Their thickness varies between 1 cm (L8, L10) and 6 cm (L1). The sedimentary section that accumulated over a sand beach deposit was overlain by organic horizons (L16) approximately 13 cm thick.

Organic matter started to accumulate in L1 ca. 1180 cal. yr B.P. at the location of Structure H, prior to the site's occupation and construction of the house. A charcoal fragment was extracted from L12, dated to 480 cal. yr B.P. A tree stump collected in the site was dated to 490 cal. yr B.P. (Table 2). This artefact was interpreted as a piece of driftwood that had formed part of the roof.

The paludification of the location nearest to the pond (0.7 m) occurred at about 1160 cal. yr BP. At 7 m, it was dated to about 2550 cal. yr B.P.; at 12 m it was dated to 2480 cal. yr B.P.; at 20 m it was dated to 2230 cal. yr B.P.; at 27 m it was dated to 2160 cal. yr B.P.; at 34 m it was dated to 2650 cal. yr B.P.; and at 43 m it was dated to 1520 cal. yr B.P. Based on these findings, we may conclude that the paludification of the nearby pond began at about 2650–2420 cal. yr B.P. in the deepest zone, in which approximately 30 cm of peat accumulated until the present time (Fig. 2, part c; Table 2).

Sedimentological Data

The grain size parameters indicate that the sediment in the sampled layers consists of fine gravel (L11), very coarse sand (L5, L13), coarse sand (L3), and medium sand (bottom sediment, L7, L9, L15) (Table 3). The sediment of all of

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TABLE 2

Radiocarbon and calibrated age of JfE1-10 site on Illutalialuk, Nunavik.

Sample and depth (cm) (see Fig. 2)	Laboratory number	Age (^{14}C yr B.P.)	Age (cal. yr B.P.) (2 σ)	Midpoint calibrated ages (cal. yr B.P.)	Age (cal. yr A.D.–B.C.) (2 σ)	Material dated
Stump from Structure H	UL-2664	460 ± 60	420–560	490	A.D. 1390–1530	Wood
Layer 1 (L1)	UL-3064	1260 ± 70	1050–1300	1175	A.D. 650–900	Decomposed organic matter
Layer 12 (L2)	UL-2670	450 ± 60	400–540	485	A.D. 1400–1560	Charcoal
Base of the Pond Monoliths						
Monolith 1-13	UL-2682	1230 ± 80	1040–1290	1165	A.D. 660–910	Organic matter
Monolith 2-25	UL-2665	2510 ± 90	2350–2750	2550	800–410 B.C.	Peat
Monolith 3-30	UL-2666	2230 ± 60	2110–2350	2230	400–160 B.C.	Peat
Monolith 4-25	UL-2667	2420 ± 60	2350–2620	2485	670–400 B.C.	Peat
Monolith 5-25	UL-2668	2140 ± 60	1990–2320	2155	370–40 B.C.	Peat
Monolith 6-30	UL-2672	2600 ± 90	2430–2870	2650	920–480 B.C.	Peat
Monolith 7-10	UL-2674	1640 ± 50	1410–1630	1520	A.D. 320–540	Peat

Distance of peat monolith (Monolith 1–Monolth 7 from the pond is, respectively: 0.7 m, 7 m,12 m, 20 m, 27 m, 34 m, 45 m.

the layers was poorly sorted. The relationship between grain size and sorting and between grain size and skewness showed variable sedimentary conditions (McManus, 1988) (Fig. 4). In fact, for sediment from the bottom and from layers L7, L9, and L15, the grain size data suggest a low energy environment; by contrast, the sediment from layers L5, L11, and L13 was deposited in a higher energy environment in which mixing resulted from the action of strong winds mixed with ice crystals, that is, from niveo-eolian transport. The sediment from layer L13 indicated intermediate conditions. The very poor sorting of all the layers suggests that the duration of the littoral and eolian processes was short.

The stereomicroscopic observation of the surface and shape (morphoscopy) of the quartz grains showed a high percentage of subangular quartz grains (between 80% and 94%). The remainder consisted of polished or angular quartz grains, which suggests that the influence of marine processes was not sufficiently strong to dull the grains. This supports the hypothesis that marine conditions were short-lived.

The S.E.M. analysis of quartz grains from every layer revealed that mechanical features such as conchoidal fractures and cracks, concentric and radial pressure marks, and crescent-shaped marks (Fig. 5, parts a, b, and c) were very prevalent on the surface of the quartz grains, which suggests that the sediments were transported by glacial processes (Le Ribault, 1977; Higgs 1979; Whalley and Langway, 1980; Gomez et al., 1988; Mahaney, 1995; Carr et al., 2000). Observation with S.E.M. also showed that these marks are very smooth (Fig. 5, part c) and the majority of quartz grains are clean, except for a few silica globules strewn on the surface (Fig. 5, parts a, c, and e). In the cavities, Neogene silica and diatoms were found, which are indicative of a marine environment (Fig. 5, parts d and f). Several quartz grains showed dissolution features that are generally produced in marine domains that are undersaturated in silica (Whalley and Langway, 1980; Whalley, 1995).

Given these findings, it is likely that the quartz grains evolved in glacial and then glaciofluvial environments before entering a beach environment characterized by high hydrodynamic conditions. Sediments were thereafter transported from the nearby beach to the site by niveo-eolian and eolian

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TABLE 3

Grain size data of sediment from the base of the section, L3, L5, L7, L9, L11, L13, and L15 from structure H, JfEl-10, on Illutalialuk, Nunavik.

Layer	Depth (cm)	Gravel (%)	Sand (%)	Silt (%)	Parameters	Values (ϕ)	Interpretation
Base	56	19	80	1	Ms	1.065	Medium sand
					Sd	1.072	Poorly sorted
					Sk	1.409	Positively skewed
L3	43–46	29	70	1	Ms	0.193	Coarse sand
					Sd	2.021	Very poorly sorted
					Sk	−0.955	Negatively skewed
L5	37–40	43	56	1	Ms	−0.803	Very coarse sand
					Sd	2.634	Very poorly sorted
					Sk	−2.265	Negatively skewed
L7	33–36	12	87	1	Ms	1.110	Medium sand
					Sd	1.056	Poorly sorted
					Sk	1.075	Positively skewed
L9	31–32	6	92	2	Ms	1.322	Medium sand
					Sd	1.175	Poorly sorted
					Sk	1.863	Positively skewed
L11	27–30	56	43	1	Ms	−1.555	Very fine pebbles
					Sd	2.905	Very poorly sorted
					Sk	0.407	Positively skewed
L13	18–25	56	43	1	Ms	−0.666	Very coarse sand
					Sd	2.282	Very poorly sorted
					Sk	0.298	Positively skewed
L15	14–17	2	97	1	Ms	1.504	Medium sand
					Sd	0.992	Moderately sorted
					Sk	2.380	Positively skewed

Ms = mean size, Sd = standard deviation, Sk = skewness.

process, as indicated by the poor sorting of the sediment (Ruz and Allard, 1995).

Macrofossil Analysis

The number of plant macrofossils found in the mineral layers were less than those found in the organic layers (0–20 macrofossils in mineral layers versus 100–1340 macrofossils in organic ones). Three macrofossil zones (M-I, M-II, M-III) were identified on the basis of the assemblages (Figs. 6 and 7).

Zone M-I (at 56–44 cm depth) is composed of two organic layers (L1 and L2) and a mineral layer (L3). In these basal layers, only woody fragments, roots, and some other remains that could not be identified because of significant decomposition were found (Fig. 6). The presence of *Salix* and *Luzula* cf. *wahlenbergii* (reindeer woodrush) remains indicates that conditions were sufficiently humid to allow the initiation of peat accumulation at around 1180 cal. yr B.P. (Fig. 7). However, peat accumulation was interrupted by eolian transport (layer L3). The presence of *Montia fontana* (water blinks) in this zone indicates that the site was occupied shortly after 1180 cal. yr B.P., because this species frequently grows on sites that have been disturbed by human activity (Blondeau and Roy, 2004). If this date is associated with human activity, it would correlate to the earlier Dorset occupation of the valley; it is far too early to be associated with the arrival of Thule Inuit to the Eastern Arctic, which did not

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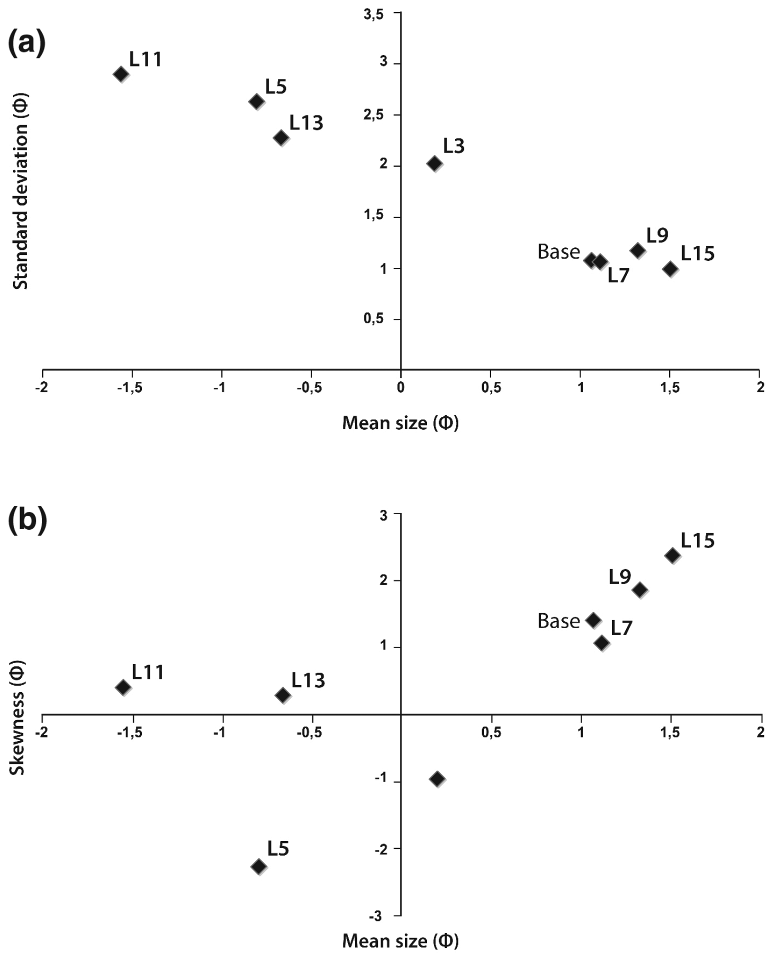

FIGURE 4. Characteristics of sedimentary environment deduced from the relationship between (a) mean size and standard deviation and (b) mean size and skewness.

occur until after A.D. 1200. While no Dorset era dates were recovered from material excavated at JfEl-10, the artifacts testify to a Dorset presence at the site; although generally undiagnostic, a few the lithic tools indicated occupation during the Late Dorset period (ca. A.D. 500–1100).

Zone M-II (44–27 cm) accumulated between ca. 950 and ca. 490 cal. yr B.P. Conditions became moister during this period, as indicated by the presence of *Andromeda polifolia* (bog rosemary), *Luzula* cf. *wahlenbegii*, and *Salix* sp. (in layers L4, L6, L8, and L10). Grains from the ubiquitous species *Empetrum nigrum* (crowberry) were found in layers L6 and L8. The presence of *Montia fontana* seeds is recurrent and their frequency is significant. This humid period was also interspersed with eolian activity that caused sand layers to form (layers L5, L7, L9, and L11).

Zone M-III (27–14 cm) accumulated between ca. 490 and ca. 260 cal. yr B.P. In layer L12, taxa from humid climates declined in favor of the fungus *Cenococcum graniforme*, but *Montia fontana* was still present. This layer is characterized by numerous charcoal fragments, which are likely traces of the Thule Inuit occupation at the site. Charcoal from this bed was dated at 480 cal. yr B.P., which is the same date as that of the tree stump taken from the site (490 cal. yr B.P.). These dates also fit between those retrieved from charcoal recovered during the excavation of Structure H's midden: 520 and 390 cal. yr B.P. A few thin organic layers (L14 and the base of L16) formed during this period, but these only consisted of highly decomposed peat. Taxa from humid climates were nonexistent, whereas eolian sediment was dominant. These data suggest cold conditions such as those associated with the cold and dry climate of the Little Ice Age (LIA) that occurred between A.D. 1500 and 1850. The youngest occupation date for JfEl-10 of 390 cal. yr B.P. places abandonment of the site not long after the beginning of the LIA—possibly at the onset of a colder phase that began A.D. 1650.

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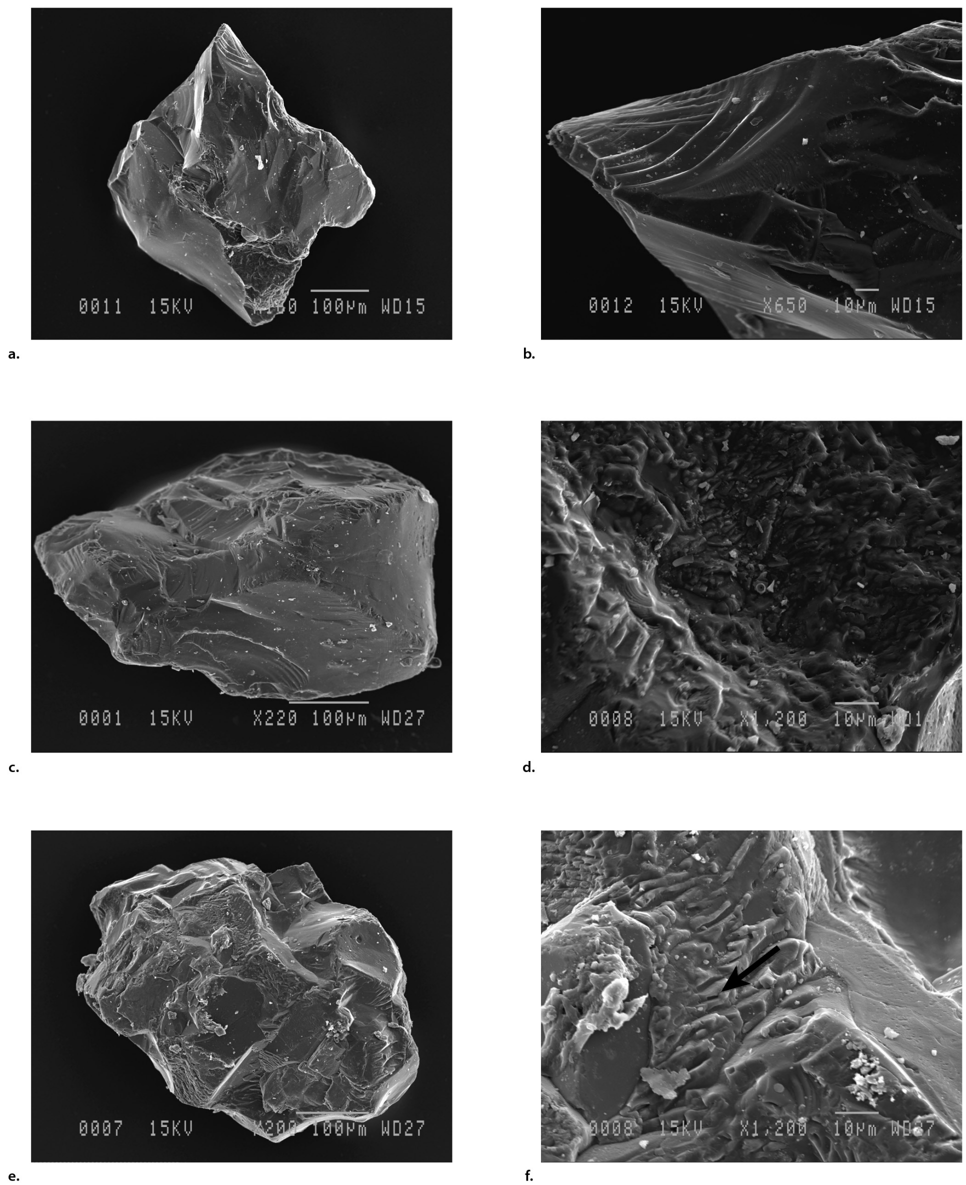

FIGURE 5. Exoscopy of the quartz grains using a scanning electron microscope: (a) angular quartz grain with polished surface; (b) step-like marks at the edge of the grain; (c) subangular quartz grain with numerous notches, crescentic and step-like marks (some of these marks are smooth); (d) Neogene silica within cavities of quartz grain; (e) subangular quartz grain with patches of Neogene silica and dissolution features; and (f) close-up.

Pollen Data

The pollen concentrations were high, varying from 112,000 to 498,000 grains cm^{-3}. These values increased between depths of 47 and 30 cm, reaching their maximum in L6. From L6 to L10, the concentration decreased significantly, reaching the lowest values in L14. Finally, the upper sample (L16) contained more than 380,000 grains cm^{-3} (Fig. 8). This high value of pollen concentration in L16 could be associated with the taphonomic conditions of the subactual undecomposed organic material. The shrub remains decreased from the bottom to the top of the sequence. In parallel fashion, herbaceous species increased (especially *Poaceae*). Pollen from the *Poaceae* was the most abundant, reaching greater than 70% in three layers (L4, L12, and L16). Three pollen zones were identified using a constrained cluster analysis that correspond to the macrofossil zones (Fig. 8).

Zone P-I (56–44 cm) is dominated by shrub and herbaceous species: *Poaceae*, which increased from L1 (22.7%) to L2 (50.7%), *Cyperaceae*, *Salix* sp., and *Ericaceae* were the most abundant taxa. Pollen grains from *Caryophyllaceae, Alnus* sp., and *Betula* were also found, but in low percentages (1%–3%).

Pollen zone P-II (44–27 cm) is characterized by higher taxonomic diversity (increasing from 13 species in P-I to 22 in P-II), as well as a higher representation of shrub, herbaceous, and tree species.

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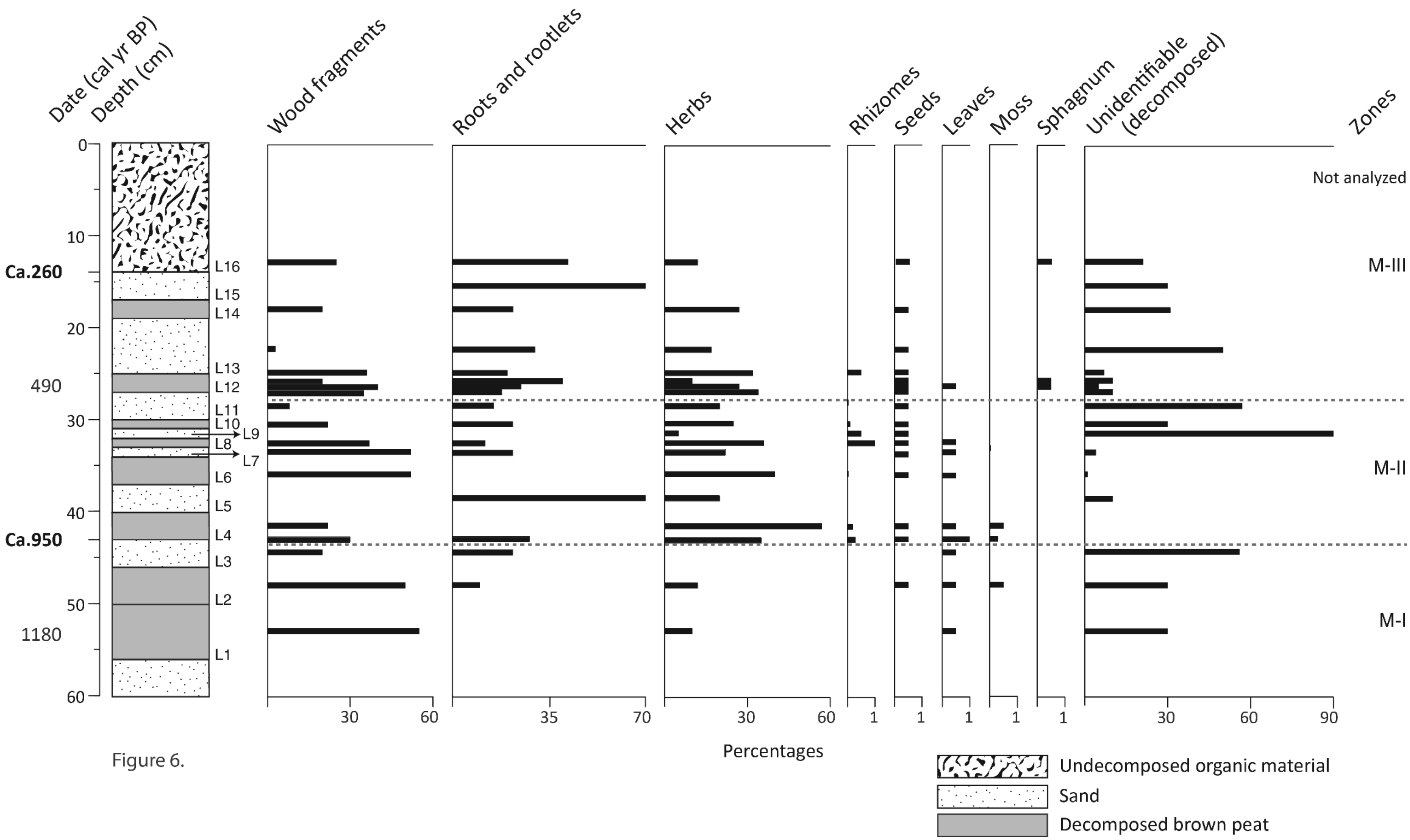

FIGURE 6. **Summary of plant macrofossil data (percentages) of the eastern edge of Structure H (JfE1-10, Quaqtaq, Nunavik).**

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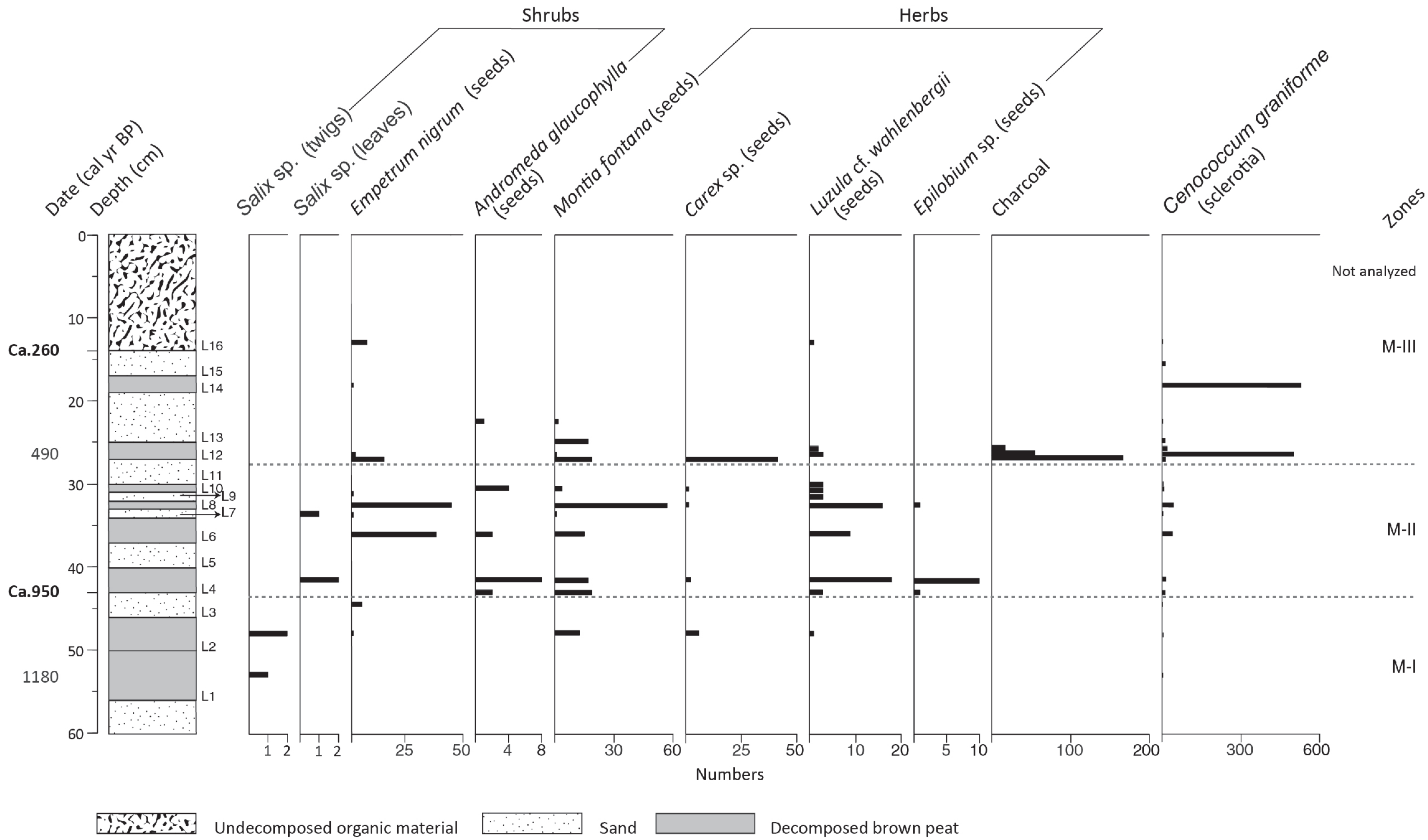

FIGURE 7. Plant macrofossil diagram (numbers) of the eastern edge of Structure H (JfE1-10, Quaqtaq, Nunavik).

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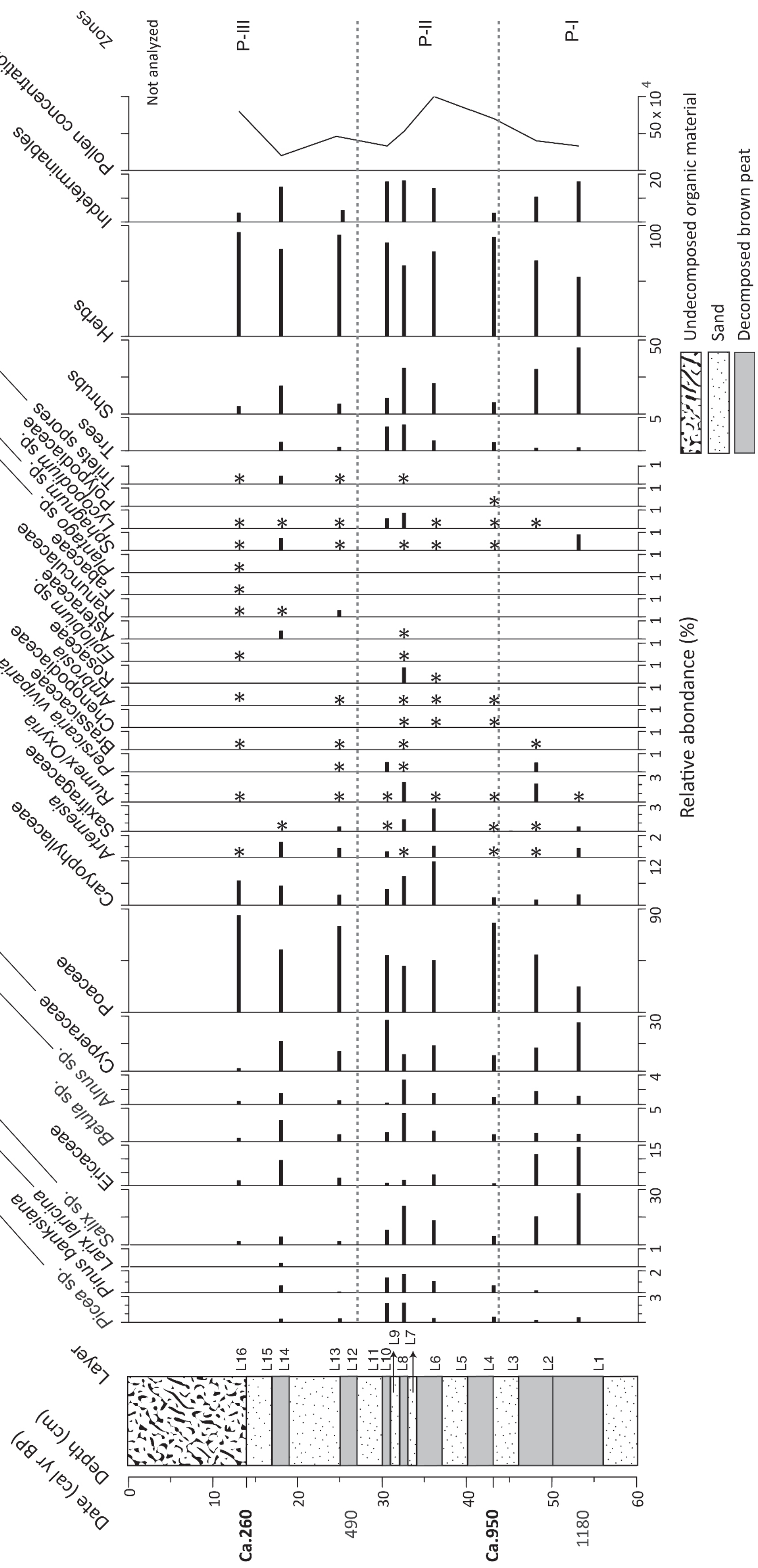

FIGURE 8. Pollen diagram (percentages) of the eastern edge of Structure H (JfEl-10, Quaqtaq, Nunavik).

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The higher values of pollen concentration could be associated with the increase in plant diversity. *Poaceae* slightly decreased (80%–40%), while *Cyperaceae*, *Caryophyllaceae, Alnus* sp., *Betula* sp., *Saxifragaceae,* and *Salix* sp. became more frequent. Pollen from *Picea* sp. and *Pinus* sp. were identified in greater percentages than in P-1. These pollen types would have derived from long-distance transport.

In Zone P-III (27–14 cm), the percentages of almost all of the taxa in P-II declined. In fact, pollen grains from *Picea* sp., *Pinus* sp., *Salix* sp., and many herbs almost disappeared, whereas those from *Ericaceae, Cyperaceae*, *Alnus* sp., and *Betula* decreased. Concomitantly, *Poaceae* attained its highest percentages (83%–85% in L1a and L16). In short, this pollen zone is characterized by a decrease in the percentage of the woody taxa and an increase in the number of herbaceous pollen taxa.

Discussion

The Physical Evolution of the Site

Arctic environments are controlled in intrinsic ways by climate and by geomorphological processes. The plant and animal resources that have supported the peoples of the Arctic since their establishment on the land are the result of a series of geological, geomorphological, and ecological processes. These processes initially affected structural formation, after which dynamic forms occurred that were directly related to the last glacial and postglacial episodes.

Illutalialuk, like the coast of Diana Bay, emerged following the retreat of the postglacial D'Iberville Sea during the Late Holocene. The study site JfE1-10 is located on the principal valley that faces northwest (Fig. 1, part b) and is characterized by a series of beach ridges at a distance of approximately 500 m from the coast on a 10%–15% slope toward the bay. The raised beach ridges are separated by long depressions that occasionally contain ponds. Together, these features provide clear evidence of the retreat of the sea.

According to the emersion curve for the Quaqtaq region (Gray et al., 1993), the emergence of the site at an altitude of 20–22 m would have occurred at approximately 4400–4600 ^{14}C B.P. Vegetation was established several meters from the study structure at approximately 2650 cal. yr B.P. (2600 ± 90 ^{14}C B.P.), whereas the first taxa to colonize the site itself did so at approximately 1180 cal. yr B.P. (1260 ± 70 ^{14}C B.P.). This means that a period of about 1500 years elapsed before the vegetation became established throughout the study site. Much later, at approximately 1000 cal. yr B.P., the Dorset people occupied the land. Artifacts corresponding to the Late Dorset period were recovered in the mixed assemblage from JfEl-10. Additionally, the grains from *Montia fontana* were found at location L2 that indicated the presence of humans at the site ca. 1000 cal. yr B.P., a date that fits well within a Late Dorset presence. This species is a type of *Portulacae* which, according to Blondeau and Roy (2004), grows in sites disturbed by humans. It has also been found on a former trading post site in Nunavut (Aiken et al., 2007) and on archaeological sites in Nunavik and Nunatsiavut (e.g., Lemieux et al., 2011; Roy et al., 2012). In this regard, the habitability of the land is determined by biophysical conditions that combined to create the relative stability of the available habitats, but which also evolved over time (Richard, 1985; Dumais and Rousseau, 2002; Hétu and Gray, 2002). Furthermore, there was a time lag between the establishment of geomorphological structures that are conducive to human habitation and the actual establishment of humans, as was also the case at Illutalialuk.

The coastline of Diana Bay and the islands in the region contain more than 100 documented archaeological sites (Plumet, 1989). Diana Island (Fig. 2, part a), the largest, contains many of those settlements. This region was home to both Paleoeskimo and Neoeskimo peoples. Moreover, at Diana Bay and elsewhere in Nunavik, Thule Inuit campsites frequently map onto Dorset sites, which can obscure archaeological interpretations. Dorset artifacts are often recovered from Thule Inuit house contexts, but their presence more likely indicates the use of sod recovered from Dorset dwellings—either adjacent or underlying—in the construction of Thule Inuit semisubterranean houses, rather than a simultaneous occupation of the site by the two cultural groups (Park, 1993; Lofthouse, 2003, 2007; Arsenault and Gendron, 2007; Pinard and Gendron, 2009).

The significant number and diversity of archaeological remains is the legacy of the biogeographical context of the bay and speaks to the suitability of the

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physical landscape for human occupation. In fact, Diana Bay is rich in faunal resources, characterized by an abundance of marine mammals and caribou (Dorais, 1997; Vézinet, 1982). It is well positioned along the migration route of walrus, beluga, harp seal, and bowhead whales. In addition, the coasts and islands in Diana Bay contain areas that (1) have access to fresh water, (2) contain peatlands from which peat can be extracted to construct houses, (3) are protected from northwesterly winds, and (4) contain soft sediment deposits from ancient beaches that could be hollowed out in order to construct semisubterranean houses. The location of site JfE1-10 satisfies all of these criteria, but according to our data, it also appears to have been exposed to prevailing winds to such an extent that sand sediments accumulated in the peat deposits.

Site Occupation in the Context of Environmental Change

The temporal evolution of the site occurred in three phases. The first phase started with the accumulation of organic material above beach sand that was carried by winds onto the site at approximately 1200 cal. yr B.P. The significant decomposition of the peat in the basal layers (L1 and L2) could have been caused either through trampling by people who occupied the structure, by local mesic conditions, or by a combination of these two factors. The latter possibility seems to be the most likely, as the site was certainly occupied at this time. The primary indications of occupation are the Dorset artifacts found through the excavation (Avataq Cultural Institute, 2003) and the macrofossils of *Montia fontana* found in this study.

The regional climate appears to have been relatively dry, as indicated by the grass-dominated pollen spectra and the accumulation of niveo-eolian sand at approximately 950 cal. yr B.P. Similar conditions occurred in the vicinity of Salluit village located about 300 km west of Quaqtaq (Fig. 1, part a); specifically, the climate was cold and dry between 1100 to 870 cal. yr B.P., as indicated by the disappearance of *Sphagnum* (Ouzilleau-Samson et al., 2010), by the growth of ice wedges (Kasper and Allard, 2001), and by the cessation of solifluction processes (Todisco and Bhiry, 2008). During this cold and mildly humid climate phase, the Dorset people occupied several sites in Diana Bay (Plumet, 1989, 1994), including site JfE1-10 (Avataq Cultural Institute, 2003; Lofthouse, 2003, 2007). Dorset people had an economy based predominantly upon marine resources, and they were highly adapted to living in a cold environment (Maxwell, 1985; Murray, 1996, 1999; Darwent, 2001).

The second phase lasted between ca. 950 and 490 cal. yr B.P. Macrofossil and pollen data indicate that conditions were humid, which encouraged a diverse and intense accumulation of plants locally and throughout the region. The niveo-eolian sand bed (L15) and the eolian sand beds (L7, L9, and L11) became thinner due to peat accumulation. Consistent with data from the Salluit region, the paleoecological data at this site shows that the climate became warm and humid between 870 and 670 cal. yr B.P., *Sphagnum* reappeared on the site, and there was a reduction of eolian activity (Ouzilleau-Samson et al., 2010). The site was also occupied during this 460 year period, as indicated by the presence of *Montia fontana*. The abundance of *Empetrum nigrum* seeds could also be related to human occupation because Inuit consume *Empetrum nigrum* (*Paurngaqutik* or crowberry) (Cuerrier, 2011), and likely also did so in the past.

The three excavated areas (Structures D and E, and Structure H's midden) yielded a mixture of Dorset and Thule Inuit artifacts, although the poor preservation restricted the recovery of Thule Inuit artifacts, which tend to be more commonly made from organic materials. Dorset artifact assemblages, on the other hand, contain a higher proportion of lithic tools that are more resistant to taphonomic attrition. According to Plumet (1989), evidence from the Thule Inuit occupation of Structure D at this site (Fig. 2, part a) was dated to 747 cal. yr B.P. (derived from 810 ± 80 yr B.P. in Plumet, 1979, 1994). Since we know that the site was also occupied by Dorset peoples, this date may belong to a Late/Terminal Dorset presence, although it is significantly later than other dated Late Dorset sites in Nunavik. More likely, the date, from unspeciated charcoal, is actually older than the occupation because it was derived from driftwood. During the 2002 excavations, charcoal was recovered from the same area (Structure D's kitchen alcove), and was dated to 500 cal. yr B.P. More recent dates recovered from the site give a range of 650 to 390 cal. yr B.P. The lower

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end of the range is quite early, and this fits with the presence of bowhead whale bones at the site, as well as an external kitchen alcove in Structure D's architecture. Both of these features are considered early traits in the Thule Inuit archaeological record. Thule Inuit are believed to have migrated from Alaska into the Canadian Arctic during the 13th century (McGhee, 2000, 2009; Friesen and Arnold, 2008; Morrison, 2009). Note also that *Montia fontana* and *Empetrum nigrum* were particularly abundant during the period between 600 and 700 cal. yr B.P. (see Fig. 7), suggesting a stronger human presence during this time. Three archaeological dates were recovered that fall in this time period: 650 and 600 cal. yr B.P. from Structure E, and 640 cal. yr B.P. from Structure D's midden.

The third climate phase began at approximately 490 cal. yr B.P. and is characterized by dry and cold conditions. There was a significant decrease in the diversity of vegetation both locally and regionally, as the encroachment of sand on the site intensified. This phase corresponds to the LIA, which was characterized by frequent variation in climate and a tendency toward cooling (e.g., D'Arrigo et al., 2003; Payette and Delwaide, 2004). The conditions of the LIA and its impact have been described in several regions in the northern hemisphere (e.g., Grove, 1988; Grumet et al., 2001; Jennings et al., 2001; Payette and Delwaide, 2004; Lemieux et al., 2011; Roy et al., 2012). In the Salluit region, the climate became generally cold and dry between 670 cal. yr B.P. and the present (Ouzilleau-Samson et al., 2010). The eolian sand influx greatly increased and *Sphagnum* disappeared. Despite these difficult conditions, the site continued to be occupied, as is evident from the charcoal fragments found at the site, the presence of a stump that was likely part of the structure of the house, and the grains of *Montia fontana*.

A zooarchaeological study of JfEl-10 demonstrated the importance of marine mammals: particularly walrus and bearded, harp, and small seals (Lofthouse, 2003, 2007). Bowhead whale bones were present to a lesser degree, but most had been removed during the 1970s' excavation of Structure H, rendering it difficult to confirm their use architecturally, as is often observed for Early/Classic Thule sites in other regions in the Canadian Arctic. The excavation of Structure E, however, uncovered two to three large whale ribs in the house walls; Structure D also contained the partial mandible of a large whale in the wall, and part of a weathered whale skull was resting on the surface of neighboring Structure E, possibly having rolled down from the adjacent wall of Structure D. Bowheads migrate through the area in spring and late fall. Caribou bones are also present and form the second most abundant animal in the assemblage (23.5% based upon bone counts identified to species) after small (ringed/harbor) seal (49.2% of bone counts identified to species) (Lofthouse, 2003, 2007). Caribou tends to be found in the area from spring until fall, before overwintering in the interior (Vézinet, 1982). The presence of migratory walrus and harp seal was used to infer that the site was occupied predominantly during fall/winter and possibly spring.

Tuvaaluk, as a result of the thickness of the ice during winter, has been described as a difficult place to hunt seal through their breathing holes (*alluit*). During fall, the bottom of bays are the first areas to freeze over, and during this time, before the ice field becomes too thick, the bottom of Diana Bay was a popular place for this type of hunt (Vézinet, 1982). Also in the fall, both harp seal and walrus pass the bay during their return migrations; walrus were known ethnohistorically to haul out at Ulliviniq in northwestern Diana Bay. A high proportion of small seal (roughly half of the identified assemblage) and the presence of harp seal and walrus remains in the assemblage suggest that the site was occupied during this season. The walrus assemblage contained a high proportion of baccula (penis bones), suggesting that this may have been a male-only haul-out, a practice that has been observed by walrus biologists (e.g., Born and Knutsen, 1997).

According to Dorais (1997), Tuvaaluk is completely frozen by late November. If this freeze-up occurred earlier, as it may well have during one of the colder phases of the LIA—the first of which began ca. 400 B.P.—it may have shrunk the window for *allu* seal hunting, and also deterred walrus from hauling out in Diana Bay. According to Born and Knutsen (1997), walrus choose to haul out on land generally when ice floes are unavailable; in the colder conditions that began ca. 400 cal. yr B.P., they may have chosen ice floes over land, making it more difficult for the inhabitants of Illutalialuk to hunt them. If a quick freeze-up of Tuvaaluk made

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small seal and walrus less accessible during this cooler period, the fall/winter camp at Illutalialuk could have become unsustainable, and its inhabitants would have needed to seek out a more profitable area for their seasonal camp—possibly across the peninsula on the northwestern Ungava Bay shore, where both seal and walrus are readily accessible in fall and early winter. The abandonment of JfE1-10 after 390 cal. yr B.P. coincided with increased cooling associated with the LIA—whether there was a causal connection remains speculative, but feasible.

Conclusion

The ability to occupy a region is highly dependent on the geomorphology of the landscape. At site JfEl-10 and on the coasts and islands of Diana Bay generally, occupation became possible several centuries after the emergence of the land. At around 2000 cal. yr B.P., the geomorphology and environment were sufficiently stable to support human settlement. Occupation periods tracked three successive environmental stages and included two distinct cultures. The first phase (1200 to ca. 950 cal. yr B.P.) was characterized by cold mesic conditions and by the Dorset occupation. Conditions became more humid beginning ca. 950 cal. yr B.P. and lasted for approximately 460 years. It is likely that the Thule occupied the site during this second phase. The third phase corresponds to the LIA (A.D. 1500–1850). At this time, the Thule Inuit reoccupied the site and used it for hunting marine mammals. The site was abandoned during a colder phase of the LIA, which may have resulted in an earlier freeze-up of Tuvaaluk that inhibited the traditional hunting of seals through breathing holes and prevented walrus from hauling out in Diana Bay.

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