The Late Wisconsinan and Holocene Record of Walrus (*Odobenus rosmarus*) from North America: A Review with New Data from Arctic and Atlantic Canada

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ABSTRACT. The Late Wisconsinan and Holocene record of the Atlantic walrus is known from numerous collections of bones and tusks from Arctic Canada and south to North Carolina, as well as from many archaeological sites in the Arctic and Subarctic. In contrast, the Pacific walrus has no dated Late Wisconsinan or early Holocene record in North America, and it may have been displaced into the northwest Pacific at Last Glacial Maximum (LGM). The Atlantic walrus rapidly exploited newly deglaciated territory, moving northward from its LGM refugium and reaching the Bay of Fundy by 12 800 B.P., the Grand Banks by 12 500 B.P., southern Labrador by 11 500 B.P., and the central Canadian Arctic Archipelago (CAA) by 9700 B.P. Its southern range limit may have retracted to the Bay of Fundy by ca. 7500 B.P. Within the CAA, walrus remains cluster in two main age groups: 9700 to 8500 B.P. and 5000 to 4/3000 B.P. This pattern strongly resembles the distribution of bowhead whale radiocarbon ages from the same area, which suggests a common control by sea-ice conditions.

Walrus remains occur in Indian culture archaeological sites as old as 7500 B.P. and, in some cases (Namu, British Columbia, and Mackinac Island, Michigan), they evidently represent long-distance human transport. They are much more common in Paleoeskimo and Neoeskimo culture sites. However, they occur in very low abundances, and generally as debitage, in sites older than Dorset (2500 B.P.). The walrus, therefore, may not have been hunted by early Paleoeskimos. Beginning with Early Dorset, walrus remains occur in definite diet-related contexts. Middle Dorset (2300 to 1500 B.P.) and late Thule (<400 B.P.) sites are missing from the High Arctic, and there may be a similar gap in the middle Pre-Dorset (3400 to 2600 B.P.). Sea-ice conditions at these times may have adversely affected availability of walrus and other marine mammal resources. Walrus is a prominent faunal element in Middle Dorset sites on the Labrador coast; this is consistent with a southward displacement of people and resources.

Key words: Pleistocene and Holocene fossil walrus, sea ice, deglaciation, climate change, archaeological faunas

RÉSUMÉ. De nombreuses collections d'os et de défenses provenant de l'Arctique canadien jusqu'à la Caroline du Nord au sud, ainsi que de nombreux sites archéologiques situés dans l'Arctique et le Subarctique attestent de l'existence du morse de l'Atlantique à la fin du wisconsinien supérieur et durant l'holocène. Par contre, en Amérique du Nord, on n'a aucun vestige du morse du Pacifique datant du wisconsinien tardif ou du début de l'holocène et on pense qu'il aurait pu être repoussé jusqu'au Pacifique du nord-ouest au dernier maximum glaciaire. Le morse de l'Atlantique a rapidement exploité les territoires nouvelle-ment libérés par le retrait glaciaire, se déplaçant vers le nord depuis son refuge naturel au dernier maximum glaciaire et atteignant la baie de Fundy vers 12 800 BP, les Grands Bancs de Terre-Neuve vers 12 500 BP, le Labrador méridional vers 11 500 BP, et le centre de l'archipel Arctique canadien (AAC) vers 9700 BP. Sa limite méridionale s'est peut-être repliée à la baie de Fundy autour de 7500 BP. À l'intérieur de l'AAC, les restes de morses se classent en deux grands groupes d'âge: de 9700 à 8500 BP et de 5000 à 4/3000 BP. Ce schéma ressemble fortement à la distribution des âges radiocarbone établis pour la baleine boréale dans la même région, ce qui suggère que la distribution des morses et des baleines était régie par les mêmes conditions de glace marine.

On trouve des restes de morse sur les sites archéologiques de culture autochtone remontant à aussi loin que 7500 BP et, dans certains cas (Namu en Colombie-Britannique et l'île Mackinac au Michigan), ils attestent d'un transport humain effectué sur une longue distance. Ils sont beaucoup plus courants sur les sites de cultures paléoesquimaudes et néoesquimaudes. On ne les trouve toutefois qu'en très petites quantités, et en général sous forme de débitages, sur des sites plus anciens que Dorset (2500 BP). Il se peut donc que le morse n'ait pas été chassé par les premiers paléoesquimaux. Avec l'arrivée du Dorset inférieur, on retrouve les restes de morse dans des contextes reliés sans équivoque à l'alimentation. Les sites du Dorset moyen (2300 à 1500 BP) et du Thulé supérieur (< 400 BP) sont absents de l'Extrême-Arctique, et il se peut qu'il y ait une lacune similaire au pré-Dorset moyen (3400 à 2600 BP). Les conditions de la glace marine à ces époques a peut-être compromis la disponibilité des ressources en morse et en autres mammifères marins. Le morse est un élément faunique dominant des sites du Dorset moyen sur la côte du Labrador, ce qui va de pair avec un déplacement vers le sud des gens et des ressources.

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INTRODUCTION

In this paper, we review and extend the radiocarbon-dated geological and archaeological record of the walrus from North America as part of a continuing effort to reconstruct environmental conditions from the Last Glacial Maximum (LGM) to the present (e.g., Dyke, 1996). We present new sets of radiocarbon dates and other data from the Canadian Arctic Archipelago (CAA; 33 new dates) and from southeastern Canada (12 new dates). Walrus remains have also been reported from many dated archaeological sites in arctic and subarctic Canada, Alaska, and Greenland, as well as from a few more distant sites. This paper assembles these new and previous age determinations, examines the archaeological context of walrus remains, and explores their paleoecological significance and potential.

DISTRIBUTION AND ECOLOGY

The modern walrus, *Odobenus rosmarus*, is the sole species of Odobenidae to have survived the Quaternary. The family is thought to have evolved from an aquatic bear-like ancestor in the Pacific in the Early Miocene (20 million years ago). Following range extension to the Atlantic 5 to 8 million years ago, prior to establishment of the Isthmus of Panama, the original Pacific forms were thought to be extinct (Richard and Campbell, 1988; Harington and Beard, 1992). However, this view has been altered by recent Japanese finds, which include a small primitive odobenine walrus with undeveloped tusks from the early Pliocene (about 4.8 million years ago), several Pliocene records of *Odobenus*, and a Middle Pleistocene find of *Odobenus mandanoensis* that is more primitive than the living species (Horikawa et al., 1992; Miyazaki et al., 1992a,b). So *Odobenus* occupied the western Pacific Ocean (at least) from the Pliocene to the Middle Pleistocene and may have evolved there in the Late Pliocene (Tomida, 1989; Miyazaki et al., 1992a). Did the modern Pacific subspecies, *Odobenus rosmarus divergens*, arise from this Pacific stock (the simpler scenario), and reach the North Atlantic via the Arctic early in the Pleistocene, as suggested by F.H. Fay (in Cronin et al., 1994; but *contra* van Bree and Erdbrink, 1990)? Or did it arise as a result of extirpation of *Odobenus mandanoensis* and repopulation from the Atlantic via the Arctic about 1 million years ago (Repenning, 1976)? It is worth noting that walrus subspecies are genetically differentiated. This fact supports the present classification, but it must be interpreted cautiously (Cronin et al., 1994). The Pacific walrus generally is distinguished from the Atlantic subspecies, *Odobenus rosmarus rosmarus*, by its larger size, larger tusks, and
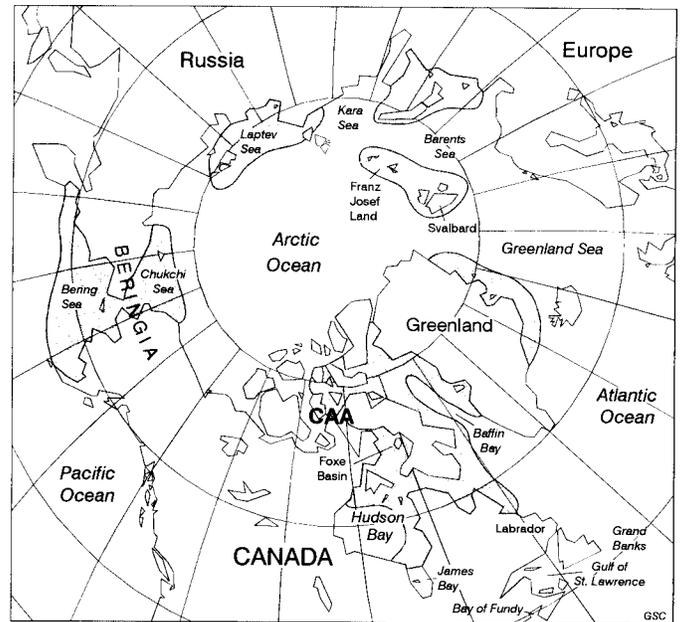

FIG. 1. World distribution of walrus showing six populations (after Richard and Campbell, 1988). Born et al. (1995) propose a more disjunct distribution for Atlantic walruses (see text).

broader snout (Fay, 1982). However, recent measurements have shown that female Atlantic walruses from Foxe Basin are larger (greater asymptotic length) than female Pacific walruses from Alaska (Garlich-Miller and Stewart, 1998).

Walrus Stocks

At the time Europeans discovered them, walruses occurred as six or more geographically isolated populations (Fig. 1), each associated with pack ice. The Pacific walrus seasonally ranges through the northern Bering Sea and the Chukchi Sea. The Atlantic walrus comprises the remaining stocks, which occupy the following areas: (1) northeastern Canada-West Greenland, extending from the Hudson Bay and northern Labrador coasts northward into the CAA; (2) central East Greenland; (3) Svalbard and Franz Josef Land; (4) Novaya Zemlya, southern Barents Sea and Kara Sea; and (5) Laptev Sea. The Laptev Sea walrus has been variously considered a distinct subspecies, *Odobenus rosmarus laptevi*, a second Pacific stock, and a stock of the Atlantic walrus (Richard and Campbell, 1988).

The present Canadian range of the Atlantic walrus is greatly reduced from its early historic range, which extended southward through the Gulf of St. Lawrence at least to Sable Island, Nova Scotia (Fig. 2; Mansfield, 1958). Except for the odd straggler, the Atlantic walrus currently
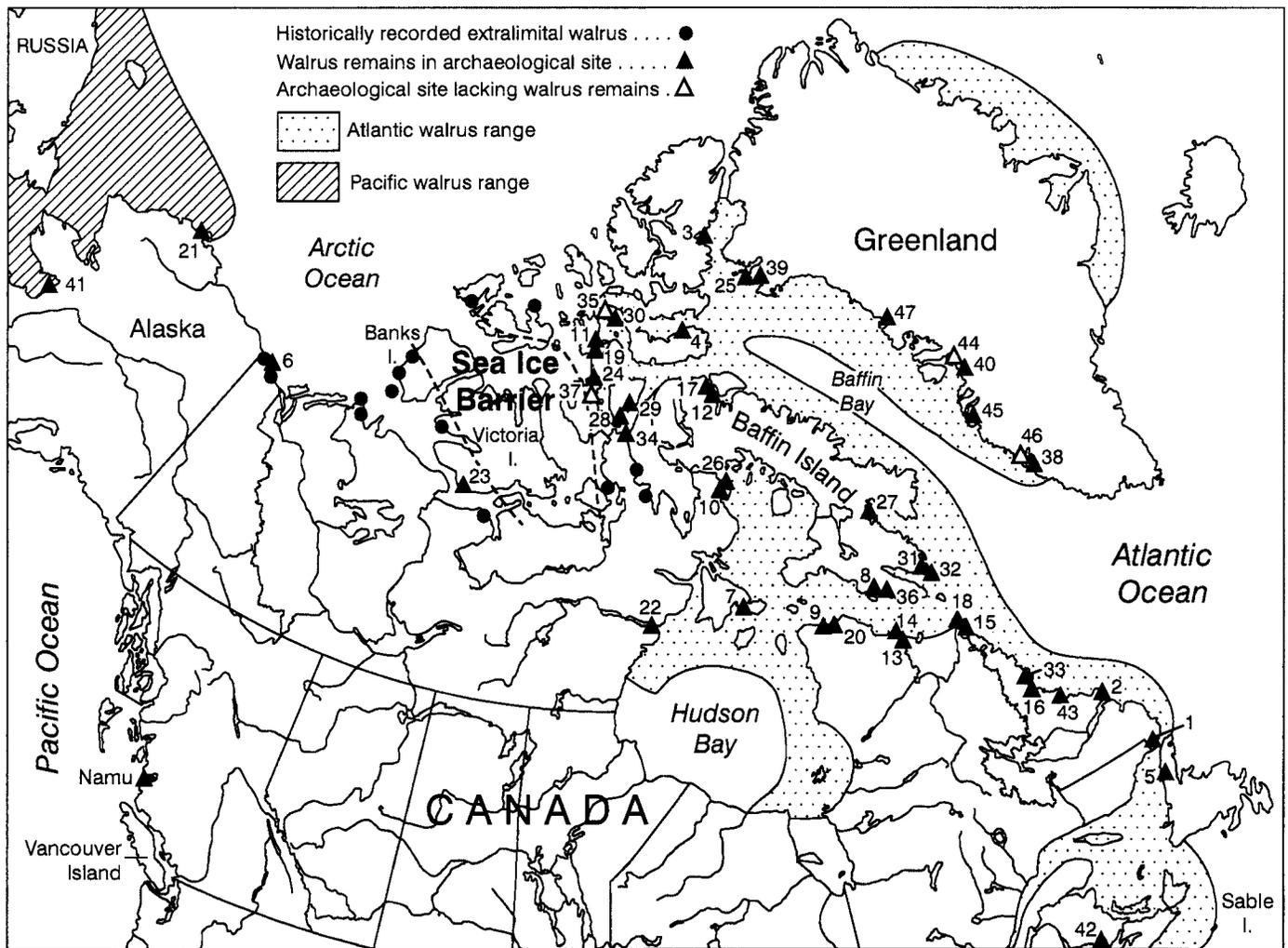
FIG. 2. Walrus distribution in the North American Arctic and Subarctic (modified from Harington, 1966), extralimital records and locations of numbered archaeological sites (cf. Tables 3 and 4).

does not range south of the central Labrador coast, as shown on Figure 1. Range reduction resulted from extirpation through hunting, mainly in the 16th and 18th centuries, of a population that evidently numbered more than 100 000 in the Gulf of St. Lawrence to Sable Island region, and there is no evidence of recolonization (Born et al., 1995). We are not aware of any direct evidence of whether this group of walruses extended only seasonally into the southern part of its range from the Subarctic, along with the sea-ice expansion, or resided there year round. However, the failure to recolonize during the present century and evidence of limited exchange between putative present stocks may suggest that the southeast Canadian walrus was a disjunct, year-round population, as is the current St. Lawrence beluga population. As such, it may have been the least ice-reliant and most warmth-tolerant of the historic walruses.

The walrus range may also have retracted from James Bay and southern Hudson Bay because of hunting pressure. The Canadian and West Greenland range (1 above) has apparently become increasingly disjunct in recent

centuries, to the point that Born et al. (1995) now propose five putative stocks within its former, possibly contiguous, range: (i) Foxe Basin, (ii) southern and eastern Hudson Bay, (iii) northern Hudson Bay-Hudson Strait- southeastern Baffin Island-northern Labrador, (iv) West Greenland, and (v) North Water (Baffin Bay-eastern Canadian High Arctic).

The probable historic range limits of the walrus within the CAA (Fig. 2) resemble those of other large sea mammals, such as the bowhead whale, narwhal, and beluga. The western limit of the Atlantic walrus in the CAA coincides with the eastern side of the M'Clintock Channel sea-ice barrier (Harington, 1966; Dyke et al., 1996b). However, the Pacific walrus, unlike the Pacific bowhead and beluga, does not now normally advance in the summer as far east as the Canadian Beaufort Sea. This suggests that its range may be limited by factors other than ice clearance, such as food availability and hunting pressure. Nevertheless, it is found occasionally as far east as Banks Island and western Victoria Island (Harington, 1966; Fig. 2) and rarely as far as Bathurst Inlet (Stewart and Burt, 1994).

The world population of Atlantic walruses is currently estimated at about 17 000 (Born et al., 1995). Within the North American Atlantic walrus range, population levels are highest in northern Hudson Bay, Foxe Basin, and the North Water area and lowest in the CAA. But before Europeans discovered their various haunts, the total population of walrus must have been at least in the hundreds of thousands. Some individual hunting expeditions to Sable Island and the Magdalen Islands (Gulf of St. Lawrence) removed thousands to tens of thousands of animals (Born et al., 1995). Prior to legislative protection in 1931, commercial exploitation of walruses for oil, ivory, and hides was extensive and unregulated (Born et al., 1995). Current harvesting rates are thought to be above sustainable levels, and there is no firm evidence of reoccupation of former ranges, even within the Arctic. The Pacific walrus population, in contrast, remains above 100 000 and is probably close to 300 000 (Kenyon, 1986).

Habitat and Mortality

Walruses inhabit shallow water areas (<100 m) where they feed on benthic invertebrates, primarily on the bivalve molluscs *Mya truncata*, *Clinocardium ciliatum*, *Serripes groenlandicus, Astarte borealis* and *Hiatella arctica*. Within their ranges, walruses are the largest consumers of this food stock. An average adult consumes 34–74 kg of food per day, discarding a comparable weight of shell material on the sea floor. Within each stock area, walruses, even today, tend to occur in regional groups of hundreds to thousands of animals, and they crop the same general areas annually (Richard and Campbell, 1988). Hence, their presence in an area indicates appreciable levels of sustained molluscan food production and shell carbonate deposition. If Holocene world populations were, conservatively, about 600 000 animals, they would have consumed about 20 000 tonnes per day or about 7.5 million tonnes per year of mollusc meat.

Walruses need hauling-out sites (*uglit*). They prefer to haul themselves out of the water onto sea ice, but will use land in summer when no ice is available. Their northern range is limited by seasonal ice clearance. They retreat in winter to the broken pack ice of the floe edge or to polynyas and major shore leads that are reliably open, or in which they can maintain holes for breathing and hauling out (Finley and Renaud, 1980; Stirling et al., 1981). Important wintering polynyas include the North Water, those around western Devon Island near the northwestern walrus range limit (Kiliaan and Stirling, 1978), and those near Fury and Hecla Strait in Foxe Basin.

Known or suspected causes of mortality include old age, disease, freezing or starving because access to water is frozen over, crushing of young during stampeding at *uglit*, and predation by polar bears (primarily on the young) and by killer whales (Richard and Campbell, 1988). Pinnipeds also occasionally wander inland and die, presumably in a state of disorientation or after freezing over

of breathing holes. This behaviour has been described for ringed seals (*Phoca hispida*) and bearded seals (*Erignathus barbatus*) in Arctic Canada (Smith and Memogana, 1977) and for crabeater seals (*Lobodon carcinophagus*) in Antarctica (Stirling and Rudolph, 1968; Stirling and Kooyman, 1971). Freezing out of walruses is mentioned by Freuchen and Salomonsen (1958). The Holocene record suggests that this may be a significant cause of death (see below).

THE FOSSIL RECORD

General Distribution and Age Patterns

The geological records of North American Pacific and Atlantic walruses contrast strongly. The Pacific walrus has no secure Late Wisconsinan to early Holocene record, whereas the Atlantic walrus has a relatively rich one.

However, the two oldest radiocarbon-dated North American Pleistocene walrus fossils are from the Pacific coast. The Qualicum Beach walrus (>40 000 B.P.; I-11617, Table 1; Harington and Beard, 1992) came from Early Wisconsinan glaciomarine sediment on Vancouver Island, and hence is about 70 000 years old. The other specimen, dredged from San Francisco harbour (California), was dated at 27 200 ± 950 B.P. (I-9994, Table 2). At face value, this date would place walruses far south of the LGM Cordilleran Ice Sheet limit before the earliest stages of buildup of the Late Wisconsinan ice sheet. That is 13 000 years before Cordilleran ice reached its southwestern limit (Clague, 1989:57; Dyke and Prest, 1987), at a time when the Pacific Northwest, although cooler than today, was largely forested. Furthermore, early deglacial marine mollusc assemblages near the ice sheet limit indicate that LGM waters there may not have been much cooler than they are today (Dyke et al., 1996a). These considerations, and the generally problematic nature of bone dates in this age range, suggest that the date on the San Francisco walrus should be conservatively interpreted as a minimum age estimate. Hence, that specimen may also date from the Early Wisconsinan or from an earlier glaciation.

With the possible exception of three undated Late Pleistocene walrus specimens from southern Alaska (Harington, 1978) and those reported from a few late Holocene Alaskan archaeological sites (GaK-2298, M-1260, SI-2158; Table 3), the Pacific walrus currently lacks a Late Wisconsinan and Holocene chronological record in North America. One wonders, therefore, if the animal may have been restricted to the south coast of Beringia and adjacent Eurasia during the last interval of emergence of the Bering Strait. Otherwise, it seems strange that so many remains would have been recovered from the Atlantic coast (below) and so few, if any, from the Pacific.

All other radiocarbon-dated North American walrus fossils are from the Atlantic stocks and are of late-glacial and postglacial age. Most or all of the historic North American range of the Atlantic walrus was covered by

TABLE 1. Radiocarbon dates on walrus collected from geological contexts. All dates are on tusks unless stated otherwise in the Reference column.

Lab. Number[1]	Age, normalized (uncorrected)	$\delta^{13}C$[2]	Lat.	Long.	Reference
Arctic					
CAMS-38024	1870 ± 40	-14.7	74.883	95.683	This paper (calcaneum)
CAMS-38025	7980 ± 40	-18.5	73.150	97.000	This paper
CAMS-38289	9300 ± 60	-15.8	72.861	93.567	This paper
CAMS-38290	1870 ± 50	-15.4	73.667	82.967	This paper (two cheek teeth)
CAMS-38433	4500 ± 60	-13.7	70.283	89.767	This paper
CAMS-38434	4670 ± 70	-14.7	70.033	86.550	This paper
CAMS-38435	990 ± 60	-14.1	75.417	96.667	This paper
CAMS-39511	910 ± 50	-15.3	76.748	94.207	This paper
GSC-2899	8690 ± 100	-17.4	75.875	79.030	Blake 1987
GSC-2951	3510 ± 50	-18.7	75.020	93.570	Blake 1987
GSC-3081	2450 ± 180	-24.7	74.030	94.850	Blake 1987 (mandible; redating of S-1392)
I-7795	7480 ± 120 (7320)	(-15)	75.717	98.417	Harington 1975 (maxillary bone)
K-5978[5]	4270 ± 90	-12.5	66.950	53.630	Bennike 1997
K-5979[5]	3030 ± 60	-11.7	62.500	50.170	Bennike 1997
K-5980[5]	1890 ± 75	-17.0	82.170	30.180	Bennike 1997
Lu-3660	1870 ± 60	-15.9	82.130	29.830	Bennike 1997
RL-834	5550 ± 380 (5390)	(-15)	78.900	75.620	Schledermann 1978
S-1392	2580 ± 65 (2420)	(-15)	74.030	94.850	Dyke 1979
S-3080	3640 ± 70 (3480)	(-15)	72.550	89.750	This paper
S-3081	9630 ± 110 (9470)	(-15)	72.540	89.730	This paper
S-3086	9540 ± 100 (9380)	(-15)	72.020	89.880	This paper
S-3087	8730 ± 110 (8570)	(-15)	72.010	89.950	This paper
S-3090	8510 ± 80 (8350)	(-15)	73.820	85.500	This paper
S-3091	1740 ± 50 (1580)	(-15)	73.820	85.500	This paper
S-3092	8640 ± 110 (8480)	(-15)	73.825	85.580	This paper
S-3093	6360 ± 80 (6200)	(-15)	70.970	89.120	This paper
S-3094	4600 ± 70 (4440)	(-15)	71.050	89.370	This paper
S-3095	4970 ± 90 (4810)	(-15)	70.730	89.100	This paper
S-3101	4480 ± 90 (4320)	(-15)	71.050	89.030	This paper
S-3512	7290 ± 160 (7150)	-16.0	72.175	94.030	This paper
S-3527	7050 ± 180 (6870)	-13.6	75.540	85.790	This paper
S-3544	1680 ± 170 (1490)	-13.8	75.960	92.140	This paper
S-3641	7250 ± 100 (7070)	-13.9	72.400	86.300	This paper
S-3642	5190 ± 90 (5000)	-12.8	70.980	86.420	This paper
S-3643	6980 ± 100 (6790)	-12.9	75.570	85.660	This paper
TO-4985	4730 ± 50	(-15)	72.820	80.440	This paper (cheek tooth)
TO-5008	4530 ± 50	(-15)	72.630	89.720	This paper
TO-5009	1630 ± 50	(-15)	73.800	87.050	This paper (ear bone; bulla)
TO-5016	4940 ± 70	(-15)	70.030	86.600	This paper
TO-5063	3480 ± 60	(-15)	76.290	93.810	This paper
TO-5960	8840 ± 80	(-15)	73.790	87.000	This paper
TO-5961	4750 ± 60	(-15)	77.055	95.510	This paper
TO-5962	8850 ± 80	(-15)	75.770	83.920	This paper
Ua-2350	4290 ± 100	(-15)	68.950	50.170	Bennike 1997
SE Canada					
Beta-16161	9860 ± 130 (9700)	(-15)	46.100	64.780	Harington et al. 1993 (humerus)
Beta-16518	11650 ± 160 (11490)	(-15)	51.480	56.975	Harington et al. 1993 (rib)
Beta-71157	2890 ± 40	-16.5	47.170	65.000	Miller 1997 (cranium)
Beta-69386	9980 ± 60	-16.9	45.250	65.500	Miller 1997 (mandible)
Beta-83412	8670 ± 50 (8510)	(-15)	51.542	55.950	This paper (vertebra)
Beta-83414	12550 ± 50 (12 390)	(-15)	44.552	49.151	This paper (cranium)
Beta-89281	10270 ± 70	-19.2	45.250	65.500	Miller 1997 (mandible)
CAMS-42768	720 ± 50	-14.1	49.917	57.800	This paper (cranium)
CAMS-43266	870 ± 40	-14.5	50.283	65.133	This paper (cranium)
CAMS-43267	9330 ± 50	-14.5	41.500	68.000	This paper
CAMS-43268	5550 ± 50	-12.6	43.767	60.000	This paper
CAMS-43269	6590 ± 50	-13.0	43.933	60.000	This paper
CAMS-43270	2180 ± 80	(-12)	43.933	60.000	This paper (cranium)
CAMS-43271	7300 ± 130	(-12)	44.333	66.233	This paper
CAMS-43272	3290 ± 140	-16.0	43.933	60.000	This paper
CAMS-43273	10130 ± 50	-14.9	49.042	66.850	This paper (cranium)
CAMS-43274	7050 ± 50	-14.1	47.267	61.717	This paper
I-9995	3820 ± 95 (3660)	(-15)	43.420	65.400	Harington & Occhietti 1988 (humerus)
TO-1554[3]	9360 ± 90	(-15)	45.080	66.750	Miller 1990 (cranium)
TO-1927[3]	12760 ± 90	(-15)	45.000	65.500	Miller 1997 (cranium)
TO-2224[4]	10500 ± 60	(-15)	45.970	73.700	Bouchard et al. 1993 (cranium)

TABLE 1 – *continued*: Radiocarbon dates on walrus collected from geological contexts. All dates are on tusks unless stated otherwise in the Reference column.

Lab. Number[1]	Age, normalized (uncorrected)	$\delta^{13}C^2$	Lat.	Long.	Reference
Pacific					
I-9994	27 200 ± 950		37.750	122.430	Harington & Beard 1992
I-11617	>40 000		49.350	124.450	Harington & Beard 1992 (rib and vertebra)

[1] Laboratory abbreviations for this and subsequent tables: Beta: Beta Analytic Inc.; BM: British Museum; CAMS: Center for Accelerator Mass Spectrometry; ETH: Eidgenössische Technische Hochschule Hönggerberg; GaK: Gakushuin University; Gif: Gif-sur-Yvette; GSC: Geological Survey of Canada; GX: Geochron; I: Teledyne Isotopes; K: Copenhagen; Lu: Lund University; M: University of Michigan; P: University of Pennsylvania; QC: Queens College; RIDDL: Radio-isotope Direct Detection Laboratory; RL: Radiocarbon Limited; S: Saskatchewan Research Council; SFU: Simon Fraser University; SI: Smithsonian Institution; TO: IsoTrace Laboratory, University of Toronto; Ua: Uppsala University Accelerator; UQ: Université du Québec à Montréal.

[2] Values inside brackets are assumed. For collagen dates we assume a value of -15 and for carboxyl CO_2 dates a value of -12.

[3] The published ages of TO-1554 (9360 ± 90) and TO-1927 (12760 ± 90) are normalized to -25 ‰ $\delta^{13}C_{PDB}$. No marine reservoir correction was applied in the original report (Miller, 1990, 1997).

[4] TO-2224 was reported by Bouchard et al. (1993) as 10 090 ± 60, after a marine reservoir correction (presumably of 410 years) was applied. Thus the age conventionally normalized is 10 500 B.P. IsoTrace laboratory does not report ^{13}C fractionation.

[5] This laboratory reports age determinations on marine mammal bones normalized for carbon fractionation to 0 ‰ $\delta^{13}C_{PDB}$. They are quoted here conventionally normalized, which increases the ages by 400 years (cf. Bennike, 1997).

glacier ice at LGM. At that time, the range was displaced far to the south, as was that of the northeast Atlantic walrus (Møhl, 1985). The record of its subsequent northward expansion is emerging as fossils are collected from the American continental shelf (Gallagher et al., 1989), the Gulf of St. Lawrence to Bay of Fundy region (Bouchard et al., 1993; Harington, 1975; Harington and Occhietti, 1988; Miller, 1990; 1997; new dates in Table 1), and southern Labrador (Harington et al., 1993). Unfortunately, however, many collections remain undated. While it is assumed that the occurrences south of the Late Wisconsinan glacial limit date from close to LGM, the shallow depth (36–40 m) of walrus finds from the New Jersey shelf should represent animals only 8000 to 9000 years old if the animals died in shallow water at the recovery sites (Gallagher et al., 1989; Dyke, 1996). If, on the other hand, these walrus remains are of LGM age, they must have been transported tens of kilometres landward during marine transgression. A detailed interpretation of such remains is not possible without age determinations.

Within the CAA, the occurrence of Holocene walrus fossils in nonarchaeological contexts is highly clustered (Fig. 3). No fossils have yet been found in areas that are known with certainty to have lain beyond the historic range of the Atlantic walrus. Although walrus remains have been found most abundantly along the northwest coast of Baffin Island, an area that is commonly portrayed as beyond the species' present or historic limit (e.g., Fig. 2), the limit here seems to be based on scanty evidence. Of the 64 arctic geological samples known to us, 1 came from Bathurst Island, 1 from Prescott Island, 3 from Somerset Island, 5 from Cornwallis and adjacent Little Cornwallis islands, 11 from Devon Island, and 41 from northwest Baffin Island (Fig. 3). Considering the lengthy time spent

in the field in these areas, the abundance of postglacial walrus fossils appears to be least in those areas that are near the historic western and northwestern range limits, and greatest along the east side of Prince Regent Inlet and southern Lancaster Sound. Although this may indicate a general increase in abundance toward Baffin Bay and toward Foxe Basin, the increase is not uniform, for there are few remains along Admiralty Inlet or Navy Board Inlet. We have not surveyed the areas of highest current population levels (Hudson Bay, Foxe Basin, northeast Baffin Bay) for walrus remains, and no geological specimens have been reported from those areas.

Nature of Occurrence

Sedimentological Context and Skeletal Elements: The dated walrus remains from southeastern Canada have been collected from raised marine sediments, both deep-water silt and clay (Beta-16518, Harington et al., 1993; TO-2224, Bouchard et al., 1993; Table 1) and littoral sand and gravel (Beta-71157, Miller, 1997, 1990; CAMS-43273, Table 1); from the modern beach, where they may have been either washed out from raised marine sediment or tossed ashore during storms (CAMS-42768, -43268, -43269, -43270, -43272; I-9995; Table 1); and from the sea floor, by clam draggers (Beta-69386, -89281, Miller, 1997; CAMS-43267, -43271, -43274, Table 1; TO-1554, -1927, Miller, 1990, 1997). In addition, one sample, a fresh-looking skull, was collected around the turn of the century from the surface at 9 m altitude and 250 m inland on the Quebec shore of the Gulf of St. Lawrence, presumably from a raised beach. It was thought that this skull might date the paleoshore, but the age determination (870 ± 40 B.P., CAMS-43266, Table 1) indicates that the animal
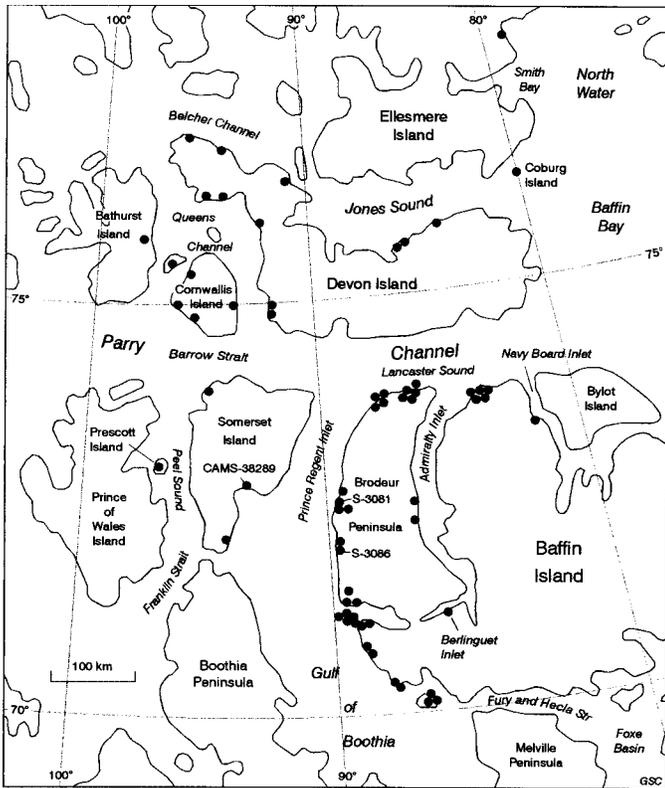
FIG. 3. Locations of walrus remains collected from geological contexts in the Canadian Arctic Archipelago (CAA). Laboratory numbers are given for samples dating close to deglaciation.
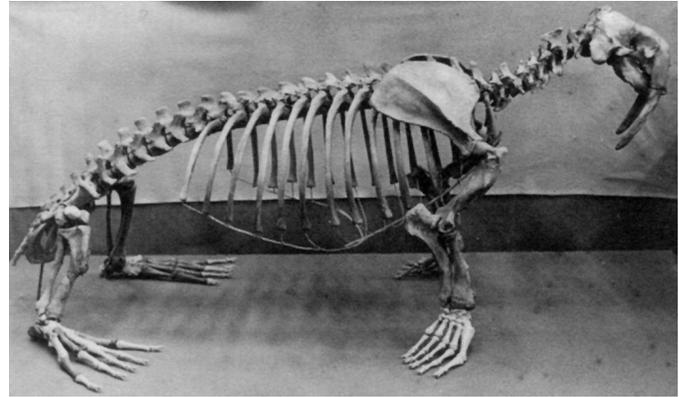

FIG. 4. Skeleton of the Moncton walrus, mounted by the Canadian Museum of Nature for display at Queen's University. The light-coloured parts are casts made from bones of a recent walrus.
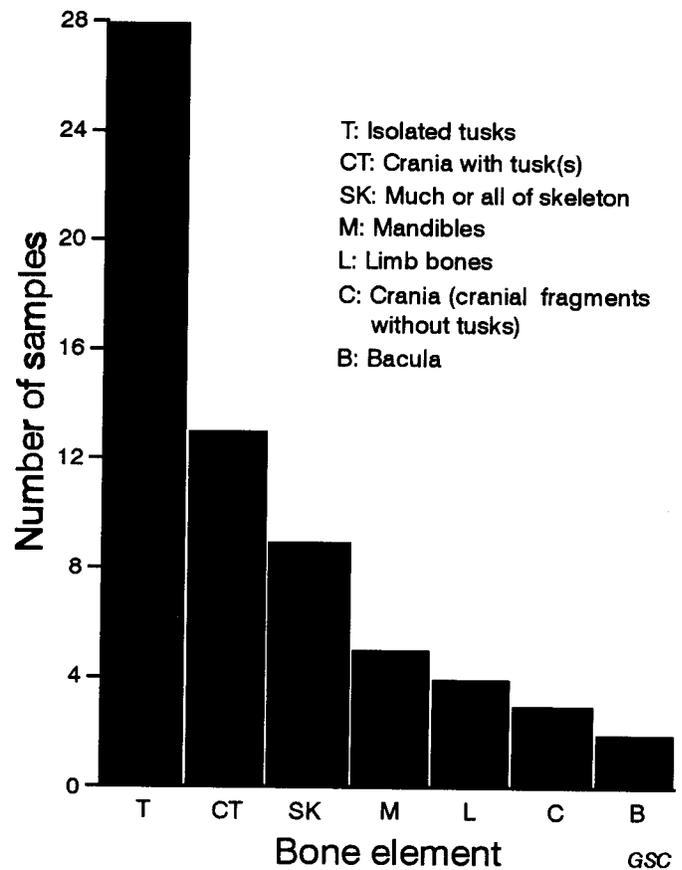

FIG. 5. Frequency distribution of walrus skeletal elements recovered from geological contexts in the Canadian Arctic Archipelago, mainly from raised beaches.

crawled inland or that the specimen was placed there. Another sample (Beta-16161, 9700 ± 130 B.P.; Harington et al., 1993) is similarly problematic. In 1871, a nearly complete skeleton was collected from a gravel pit of the Intercolonial Railway at about 110 m altitude near Moncton, New Brunswick (northeast of 42, Fig. 2) by a crew working under the direction of Sir Sandford Fleming (Fig. 4; skeleton mounted on display in the Biology Department, Queen's University, Kingston, Ontario). The site is far above the generally accepted level of the postglacial marine limit in this region, which is at about 20 m (Grant, 1989). Indeed, local relative sea level was below present by 9700 B.P. (Grant, 1989; Dyke, 1996). It seems probable (see below) that this animal wandered inland and died, to be later buried in fluvial gravel.

Because much of southeastern Canada has experienced continuous Holocene submergence and the raised marine sediment there is of Late Pleistocene age (Grant, 1989), a strongly biased age distribution will result if only those specimens from raised marine sediment are dated. It is important, therefore, to determine the ages of the specimens from the modern beach and from the sea floor.

Most walrus remains in the CAA were found on the surface of or partly buried in raised beach gravel. Isolated tusks are by far the most common remains (Fig. 5). Some of these show signs of gnawing by caribou (cf. Sutcliffe, 1977). Crania containing tusks (or tusk fragments), and somewhat less commonly other teeth, are the next most common find,

followed by mandibles, limb bones, cranial fragments without tusks, and penis bones (bacula). More extensive bone accumulations, those representing much or all of a skeleton, are uncommon. Limb bones appear to be common only along coastal segments with abundant walrus remains.

Although a taxonomic discussion of the walrus specimens mentioned here is beyond the scope of this paper, dimensions of some tusks that can be pertinent in this respect are given in Table 2. It seems reasonable to con-

TABLE 2. Dimensions (cm) of dated walrus tusks.[1]

Sample	Length	Diameter (Max)	Circumference	Weight (g)	Comments
CAMS-38025	21.7	4.8			Nearly complete but weathered tusk
CAMS-38433	15.0	5.2			Fragment with part of root cavity; chewed by ungulate
CAMS-38434	17.1	3.45			Fragment; both tip and root cavity missing; chewed by ungulate
S-3080	17.5	6	17	383	Fragment
S-3081	35.5	4.5	12	471	Complete; 20 root ridges on upper half; root cavity 1 cm deep
S-3086	35.5 (45.5)	6.5	18	1023	Worn tip and anterior edge exposing secondary dentine; estimated 10 cm missing
S-3087	28.5	4.5	13.5	451	Fragment; both tip and root cavity missing; 3 cm diameter at tip
S-3090	28.7	6.8	18	638	Nearly complete; root cavity 6.5 cm deep; 14 root ridges on upper half with 1 cm spacings
S-3091	47.0 (55.0)	6.5	17.2		Worn tip (diameter 3 cm); estimated 8 cm missing; root cavity 3 cm deep
S-3092	35.5	8.5	22	1030	Broken tip (diameter 3 cm); root cavity 2.5 cm deep
S-3093	24.6	4	11		Fragment, root end; tip diameter 3.1 cm; root cavity 4.5 cm deep; end chewed
S-3094	28	6	16	659	Fragment; worn tip diameter 4.5 cm
S-3095	56.4	7.2	18.6		Complete tusk, slightly worn tip (1.5 cm diameter); root cavity 2 cm deep
S-3101	17	3.8	10.5		Largest of two fragments
S-3527	37.2	3.9			Complete
S-3544	44.5	5.4			Complete
S-3641	40	6.5			Complete but weathered
S-3642	38	7.2			Nearly complete but weathered (tip diameter 3 cm)
S-3643	33	3.9			Complete
TO-5008	26.4	5.4	14		Complete; root cavity 9.5 cm deep
TO-5063	23	5.5			Fragment
TO-5960	15	5			Root end fragment
TO-5961	12.5	3			Fragment
TO-5962	21	4.3			Nearly complete

[1] Straight-line measurements were made with ruler and squares. Estimated accuracy is ± 2 mm.

clude (e.g., Harington, 1966; Bennike, 1997) that postglacial remains from southeastern Canada, and from sites east and north of the sea-ice barrier in the central Arctic (Fig. 2), are either forerunners of, or are identical to, the Atlantic walrus, *Odobenus rosmarus rosmarus.* Furthermore, results of a preliminary quantitative analysis of 72 adult male and 20 adult female postglacial walruses from the Atlantic Provinces are worth noting. These data, assembled by the late F.H. Fay and C.R. Harington, led Fay (pers. comm. to CRH, 1992) to observe that one of the most distinctive characters of this group, apart from relatively large size, is the enormous size in males of the upper incisors (I^3), which are often larger than the postcanines. Although this condition is unusual in modern Atlantic walruses, it is rather common in Pacific males.

Crawlers, Sinkers, and Floaters: In most instances, the nearly complete skeletons found in the CAA represent animals that appear to have crawled inland and died. Eight of the 38 radiocarbon-dated CAA walruses (21%), five of which were nearly complete skeletons, plot well above any probable contemporaneous relative sea level position. One of these specimens, a nearly complete skeleton enclosed in sand at 103 m altitude, the approximate postglacial marine limit on northern Somerset Island, was reported earlier (Dyke, 1979). An age of about 9000 years was anticipated from the elevation, but an age of 2420 ± 65 B.P. (S-1392) was determined. This age was confirmed on redating at 2440 ± 180 B.P. (GSC-3081, Table 1). Located highest of this group of young-but-high walrus remains was a skull with tusks and a scatter of other bones found at 250 m altitude, about 150 m above the limit of postglacial marine submergence and 15 km inland, on northwestern Devon

Island. Its age was determined to be 920 ± 50 B.P. (CAMS-39511). Another skeleton and a mummified hide of very recent age (undated) were found at a high elevation in the same region. We also report here age determinations on two of the four walrus skeletons mapped by Thorsteinsson (1958) on Cornwallis and Little Cornwallis islands. Both are from the altitudes of early Holocene raised shorelines, but their ages proved to be 990 ± 60 B.P. (CAMS-38435 at 70 m) and 1870 ± 40 B.P. (CAMS-38024 at 60 m). Figure 6 illustrates the carcass of a walrus found 2.5 km inland on Cornwall Island in July 1997. Judging from the limited decomposition, this animal had died the previous winter.

Similarly, of the few walrus remains from Svalbard that have been radiocarbon-dated, two are from complete skeletons found at high elevations 3 km and 7.5 km inland. Their recent ages (1330 ± 60 B.P., T-3452 and 540 ± 60 B.P., T-3453) "...show that the animals have been able to move over impressive distances on land. The reason why they made such fatal journeys (or mistakes?) is not known, but similar behavior is known from other animals. Finds of mummified seals in Dry Valleys, Antarctica, prove that seals sometimes lose the direction to the sea and move inland until they die." (Lauritzen et al., 1980: 68; see also Stirling and Kooyman, 1971). Another unpublished young date on a walrus from Svalbard is also evidently on a "crawler" (O. Salvigsen, pers. comm. 1997). We have found no reference to this behaviour as a significant cause of mortality in the biological literature. Perhaps this behaviour is a cause of death that has left an exaggerated expression in the Holocene fossil record relative to the proportion of deaths attributable to it; or perhaps this is a significant cause of walrus mortality, at least in the High

FIG. 6. Carcass of a walrus on eastern Cornwall Island, 2.5 km inland, late July 1997. This animal presumably expired while crawling inland during the previous winter. Signs of scavenging are limited to minor tooth marks on a front flipper.

Arctic, if not generally (see discussion of Moncton walrus above).

Apparently the remains of walruses that crawl inland and die are less subject to being scattered than are those that die on the shore or at sea, apart from the minor effects of solifluction and cryoturbation. Because these "inland" remains would be readily discovered by scavengers (the most powerful being the polar bear, which can pick up scent for great distances), scavengers apparently are not the most important agents of disarticulation and scattering of bones. However, the preponderance of isolated bone elements amongst the non-crawlers indicates extensive disarticulation and movement prior to deposition. The most probable agents for this are waves and sea ice acting on either floating or stranded remains, but we know of no descriptions of disarticulation by natural processes that would aid interpretation of geological remains. The dominance of tusks among recovered elements probably indicates selective preservation of this dense material, for several other less dense bone elements (skulls, scapulae, limb bones) are comparable in size or larger (e.g., Lyman, 1994).

Five of the dated arctic walrus remains, when plotted against sea level curves, appear well below their contemporaneous sea levels. These probably represent animals that died on the sea ice or in the water and sank to the bottom during the summer. Some of the deaths on the sea ice may also represent "crawlers" that died after being frozen out, though we have no way of identifying the remains as such. In the long run, crawlers are as likely to wander offshore as overland, if we assume that overland travel does not represent disorientation; but presumably some of the offshore crawlers survive by regaining access to the water. The remaining dated samples (62%) plot reasonably close to their contemporaneous sea levels, as established by dates on other materials (Dyke and Hooper, unpubl. data). They probably represent either animals that died ashore at *uglit* or animals whose remains rafted

ashore after they died on the sea ice. From this we conclude that the dated remains of a walrus are almost equally likely to represent or not to represent a paleo-shoreline.

Relative Abundances of Walrus and Bowhead Whale Remains

In the same general region of the CAA (Fig. 3), we have excavated the remains of about 1200 bowhead whales (Dyke et al., 1996b). Bowhead remains are thus about 20 times more abundant than walrus remains, although postglacial walrus populations were at least comparable to, and probably much greater than, those of the bowhead. This contrast might be explained in two ways. First, since walrus bone elements are much smaller than those of bowheads, they are less likely to protrude from raised beach deposits. Second, walruses tend to sink during the summer (Nelson, 1969); therefore, they can be expected to have a lower stranding potential overall than bowheads, which are buoyant throughout their annual residency in the Arctic.

The relative abundance of walrus and bowhead fossils from southeastern Canada is the inverse of that in the CAA: a few tens of walrus fossils are known, but only two bowheads. A partial explanation may be that many of the fossils were recovered from the sea floor by fishermen dragging the bottom for clams, a procedure that works in favour of recovering smaller objects. However, walrus remains are also somewhat more common in Late Pleistocene raised marine sediment in this region than are bowhead bones.

Normalization and Correction of Ages

The available radiocarbon age determinations on North American walruses collected from geological contexts are compiled in Figure 7 and Table 1. These ages were determined for the collagen (protein) fractions of bones and ivory and are normalized to $\delta^{13}C_{PDB}$ = -25‰, either using the measured isotopic fractionations or assuming a fractionation of -15‰. No marine reservoir correction has been established for the walrus in this region and none is applied here. However, the reservoir effect could render the normalized walrus ages several centuries too old, and this difference is critical when comparing the geological record to the archaeological record. Nevertheless, we caution against applying a single reservoir correction to all marine organisms, even within a region, because different carbon pathways are probably involved in the production of different organic carbon and carbonate components. For example, Dyke et al. (1996c) reasoned that a lesser marine reservoir correction might be appropriate for bowhead whale bone collagen dates than for marine mollusc shell carbonate dates in the same area (about 200 years vs. 400 years). This is because the carbon in the mollusc shells is deposited in isotopic equilibrium with the dissolved bicarbonate in the sea water, whereas that in the bowhead
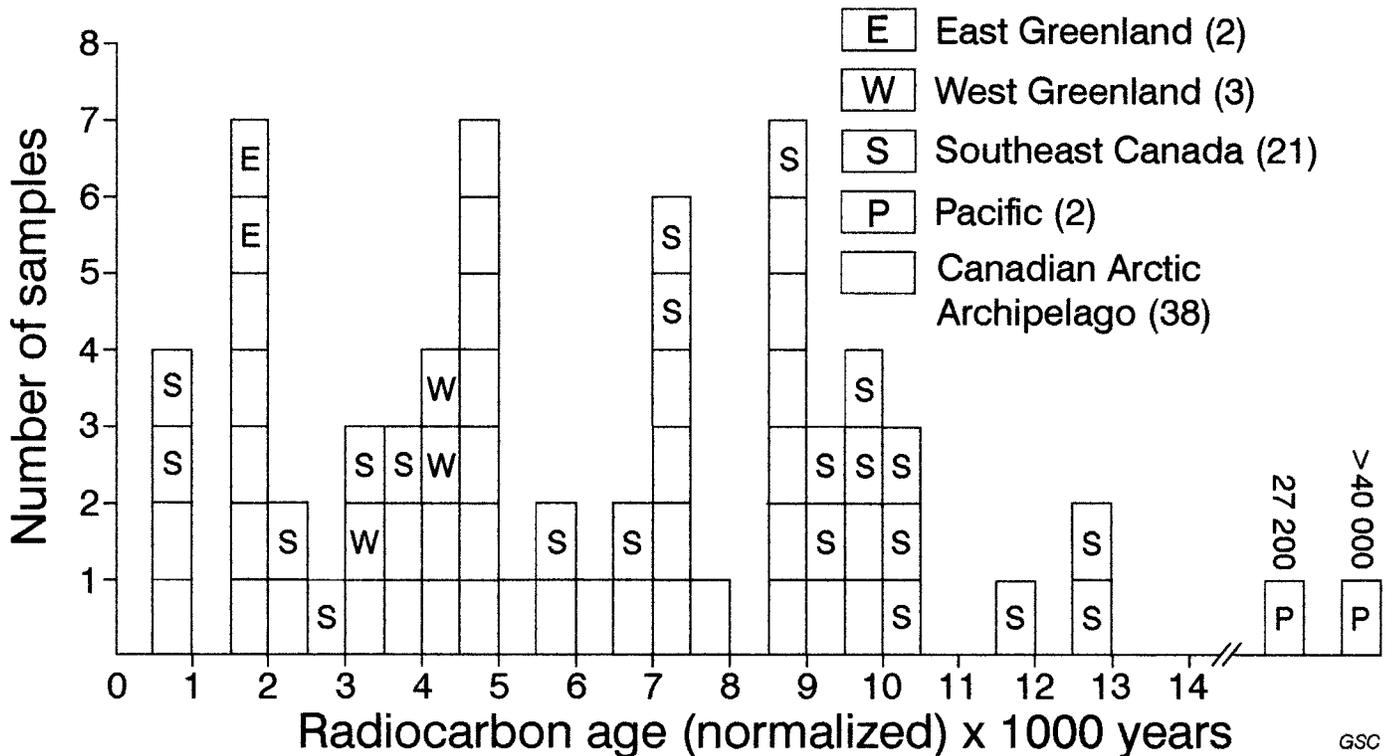
NORTH AMERICAN WALRUS DATES

FIG. 7. Frequency distribution of radiocarbon ages on walrus remains from geological contexts in North America and Greenland.

whale bone collagen is not; instead, its carbon fractionation resembles that in the bowhead's zooplankton diet.

Pertinent to this question is Schledermann's (1990: 331) report that "a date of 115 ± 40 B.P., obtained by [A.J.] Sutcliffe (pers. comm. 1981) on walrus bone associated with 19th-century hunting activities near the abandoned Bache Peninsula RCMP station, also seems to support the contention that the reservoir effect, at least in this region, is far less at variance with the 'correct' timing of events than appears to be the case in other areas of the Arctic (Arundale, 1981)." We would qualify this to mean that the appropriate reservoir *correction* for age determinations on walrus collagen may be less than the reservoir correction appropriate for marine shells, which tend to reflect the full reservoir *age* (i.e., full effect). The date referred to above is BM-1751 (Table 3; Burleigh et al., 1982). This date has been normalized for isotopic fractionation, but the collector describes it as a "surface find assumed contemporary with occupation of MP Sta [RCMP station], ca 1926-1952" (Burleigh et al., 1982:273). After discovery of a general error in its age determinations, the laboratory reported a revised age for this sample of 210 ± 100 B.P. (BM-1751R; Bowman et al., 1990). If the walrus was killed during occupation of the station, a reservoir correction of $185-210$ years is indicated. On Willows Island in outer Frobisher Bay, Baffin Island, a nested alignment 25 m long of walrus mandibles has been dated to 470 ± 60 B.P.

(Beta-61073; no marine reservoir correction; Manley and Jennings, 1996). This feature is ascribed to a Paleoeskimo or Inuit hunting ritual, and the description of the bone indicates some antiquity (Fitzhugh and Olin, 1993: 114). The date thus places a generous upper limit on the reservoir correction for walrus in that area.

Chronology

Southeastern Canada: The oldest dated postglacial walrus remains derive from the Grand Banks to Bay of Fundy region. These probably represent the northward spread of the LGM refugial population, which had been displaced south of Long Island, New York (Gallagher et al., 1989). The earliest available date on this group is $12\,760 \pm 90$ B.P. on a specimen from the Bay of Fundy (TO-1927; Miller, 1997). This date closely follows deglaciation, as perhaps do the specimen from 60 m water depth on the Grand Banks of Newfoundland dated at $12\,550 \pm 50$ B.P. (Beta-83414, normalized; Table 1) and another from southeastern Labrador dated at $11\,490 \pm 120$ B.P. (Beta-16518, Harington et al., 1993; Table 1). Half of the available dates from the region exceed 9000 B.P. The remaining age determinations span the interval 8700 to 700 B.P.

The number of dated specimens remains too small to demonstrate confidently that southeastern Canada was continuously occupied by walruses throughout postglacial

TABLE 3. Published radiocarbon dates on archaeological sites or site components reporting walrus remains in North America (see also Table 4).

Lab. Number	Material dated	Context	Age[1]	Lat.	Long.	Reference (Site No., Fig. 2)
I-8099	charcoal	Maritime Archaic	7530 ± 140	51.475	56.880	Tuck, 1977 (1)
SI-2306	charcoal	Maritime Archaic	7255 ± 115	51.475	56.880	Tuck, 1977 (1)
SI-2146	charcoal	Maritime Archaic	4650 ± 60	54.450	57.430	Fitzhugh, 1978 (2)
RIDDL-320	collagen	Arctic STT	4280 ± 200	69.360	139.530	Cinq-Mars, 1991 (6)
Y-1291	marine shell	Woodland	1880 ± 80	45.075	67.042	Wilmeth, 1978; Stewart, 1974 (42)
Beta-27515	walrus bone (ETH-4584)	Indian?	975 ± 60	45.750	84.500	This paper
GSC-3261	driftwood charcoal	Independence I	4400 ± 110	78.900	75.617	Schledermann, 1990 (3)[4]
GSC-3362	driftwood charcoal	Independence I	4250 ± 60	78.900	75.617	Schledermann, 1990 (3)[4]
TO-993	charred willow	Independence I	3940 ± 70	78.920	75.167	Schledermann, 1990 (3)
K-588	wood	Sarqaq	2960 ± 110	64.420	50.420	Møhl, 1972 (38)
K-4820[2]	turf	Sarqaq	3150 ± 80	68.583	51.083	Grønnow, 1994 (40)
K-4823[3]	turf	Sarqaq	3980 ± 85	68.583	51.083	Grønnow, 1994 (40)[4]
K-5127	seal bones	Sarqaq	3570 ± 80	68.583	51.083	Grønnow, 1994 (40)
K-5864[2]	caribou bones	Sarqaq	2860 ± 80			Møberg, 1998 (45)
K-6192[3]	caribou bones	Sarqaq	3670 ± 90			Møberg, 1998 (45)
Beta-15390	wood	Pre-Dorset	3680 ± 90	75.670	83.670	Helmer, 1991 (4)
Beta-15391	willow? charcoal	Pre-Dorset	3800 ± 90	75.670	83.670	Helmer, 1991 (4)
Beta-20781	driftwood	Pre-Dorset	3770 ± 180	75.670	83.670	Helmer, 1991 (4)
S-2484	caribou bone	Pre-Dorset	3930 ± 95	75.670	83.670	Helmer, 1991 (4)
TO-1638	charred willow	Pre-Dorset	3440 ± 50	79.117	76.150	Schledermann, 1990 (3)
Beta-49757	charcoal	Groswater Dorset	2090 ± 70	50.700	57.350	Renouf, 1994 (5)
Beta-49759	charcoal	Groswater Dorset	2540 ± 160	50.700	57.350	Renouf, 1994 (5)
Gif-1946	charred fat	Dorset	1680 ± 90	60.720	69.470	Plumet, 1985 (13)
P-75	bone	Dorset, Early	2508 ± 130	64.170	83.250	Maxwell, 1985 (7)[4]
P-76	bone	Dorset, Early	2630 ± 128	64.170	83.250	Maxwell, 1985 (7)
GaK-1280	sod, twigs	Dorset, Early	2360 ± 100	62.650	69.620	Maxwell, 1980 (8)
GSC-702	walrus, seal bone	Dorset, Early	2200 ± 130	62.260	75.560	Lowdon et al., 1969 (9)
GSC-703	walrus bone	Dorset, Early	2630 ± 130	62.260	75.560	Lowdon et al., 1969 (9)[4]
GX-6072	charred vegetation	Dorset, Early	2780 ± 140	78.877	75.633	Schledermann, 1990 (3)[4]
P-213	walrus tusk	Dorset, Early	3070 ± 129 (2910)	69.380	81.800	Maxwell, 1980 (10)[4]
S-880	caribou bone	Dorset, Early	1880 ± 90	73.025	80.630	Mary-Rousselière, 1976 (17)
S-1673	muskox bone	Dorset, Early	2210 ± 120	75.500	97.270	Helmer, 1980 (11)
SFU-81	muskox bone	Dorset, Early	2330 ± 120	75.500	97.500	Helmer, 1981 (11)
SFU-82	fox bone	Dorset, Early	2530 ± 120 (2470)	75.500	97.270	Helmer, 1981 (11)
P-62	charred seal bone	Dorset, Mid	2220 ± 200 (2060)	64.000	83.000	Maxwell, 1985 (7)
P-698	charred fat	Dorset, Mid	2608 ± 50	62.650	69.650	Maxwell, 1985 (8)[4]
S-590	bone	Dorset, Mid	1510 ± 135	72.730	80.220	Wilmeth, 1978 (12)
S-671	bone	Dorset, Mid	2405 ± 80	72.730	80.220	Arundale, 1981 (12)[4]
SI-2150	charcoal	Dorset, Mid	1775 ± 55	56.580	61.080	Cox and Spiess, 1980 (16)
SI-2151	charcoal	Dorset, Mid	1470 ± 100	56.580	61.080	Cox and Spiess, 1980 (16)
SI-2152	charcoal	Dorset, Mid	1335 ± 90	56.580	61.080	Cox and Spiess, 1980 (16)
SI-2532	charcoal	Dorset, Mid	1500 ± 95	56.580	61.080	Cox and Spiess, 1980 (16)
SI-2533	charcoal	Dorset, Mid	1775 ± 55	56.580	61.080	Cox and Spiess, 1980 (16)
SI-2534	charcoal	Dorset, Mid	1935 ± 95	56.580	61.080	Cox and Spiess, 1980 (16)
SI-2980	charcoal	Dorset, Mid	1555 ± 90	56.750	60.917	Cox, 1978; Spiess, 1978 (33)
SI-2990	charcoal	Dorset, Mid	2645 ± 65	56.750	60.917	Cox and Spiess, 1980 (33)
SI-3009	wood	Dorset, Mid	1510 ± 60	60.500	64.670	Maxwell, 1985 (15)
SI-3886	charcoal	Dorset, Mid	1495 ± 70	60.500	64.670	Jordan, 1980 (15)
SI-3887	charcoal	Dorset, Mid	2000 ± 75	60.500	64.670	Jordan, 1980 (15)
SI-3888	charcoal	Dorset, Mid	1345 ± 70	60.500	64.670	Jordan, 1980 (15)
SI-3889	charcoal	Dorset, Mid	2240 ± 80	60.500	64.670	Jordan, 1980 (15)
SI-3890	charcoal	Dorset, Mid	1395 ± 70	60.500	64.670	Jordan, 1980 (15)
SI-3892	walrus bone	Dorset, Mid	2170 ± 70 (2010)	60.500	64.670	Jordan, 1980 (15)
SI-3997	wood	Dorset, Mid	1520 ± 60	60.500	64.670	Jordan, 1980 (15)[4]
BM-1754	walrus bone	Dorset, Late	1135 ± 40	79.120	76.190	Burleigh et al., 1982 (3)
BM-1754R	walrus bone	Dorset, Late	1150 ± 100	79.120	76.190	Bowman et al., 1990; revision of BM-1754
GSC-2757	charred willow	Dorset, Late	1180 ± 70	79.120	76.190	Schledermann, 1996 (3)
GSC-2834	charred willow	Dorset, Late	1150 ± 60	79.120	76.190	Schledermann, 1996 (3)
GSC-3141	charred willow	Dorset, Late	1110 ± 70	79.120	76.190	Schledermann, 1996 (3)
GSC-3406	charred bone	Dorset, Late	980 ± 50	78.920	75.600	Schledermann, 1990 (3)
QC-625	charcoal	Dorset, Late	815 ± 110	60.930	69.980	Julien, 1980 (14)
S-848	caribou bone	Dorset, Late	1590 ± 100	73.025	80.630	Mary-Rousselière, 1976 (17)
SFU-85	fox, bear, and muskox bone	Dorset, Late	1440 ± 120	75.500	97.270	Helmer, 1981 (11)
SFU-87	muskox bone	Dorset, Late	1520 ± 200	75.500	97.500	Helmer, 1981 (11)
SI-3864	wood	Dorset, Late	670 ± 60	60.500	64.670	Jordan, 1980 (15)
TO-1557	charred willow	Dorset, Late	990 ± 50	78.920	75.600	Schledermann,1990 (3)
TO-2518	caribou antler	Dorset, Late	1020 ± 50	75.583	95.833	Helmer et al., 1993 (11)
TO-3747	caribou bone	Dorset, Late	1550 ± 50	75.583	95.833	Helmer et al., 1995 (11)

TABLE 3 – *continued*: Published radiocarbon dates on archaeological sites or site components reporting walrus remains in North America (see also Table 4).

Lab. Number	Material dated	Context	Age[1]	Lat.	Long.	Reference (Site No., Fig. 2)
TO-3748	caribou bone	Dorset, Late	780 ± 50	75.583	95.833	Helmer et al., 1995 (11)
TO-3749	caribou bone	Dorset, Late	1030 ± 50	75.583	95.833	Helmer et al., 1995 (11)
TO-4532	caribou antler	Dorset, Late	1450 ± 60	75.583	95.833	Helmer et al., 1995 (11)
TO-4533	muskox horn core	Dorset, Late	1060 ± 80	75.583	95.833	Helmer et al., 1995 (11)
TO-4534	muskox bone	Dorset, Late	920 ± 50	75.583	95.833	Helmer et al., 1995 (11)
TO-4535	caribou antler	Dorset, Late	930 ± 120	75.583	95.833	Helmer et al., 1995 (11)
UQ-88	charcoal	Dorset, Late	490 ± 80	60.930	69.980	Julien, 1980 (14)
M-1260?	charcoal	Norton	2720 ± 130	64.500	161.500	Dumond,1984 (41)
Beta-33046	charcoal	Thule	740 ± 50	60.080	64.250	Fitzhugh, 1994 (18)
Beta-33047	charcoal	Thule	870 ± 70	60.080	64.250	Fitzhugh, 1994 (18)
BM-1753	walrus vertebra	Thule	360 ± 25	79.120	76.190	Burleigh et al., 1982 (3)
BM-1753R	walrus vertebra	Thule	560 ± 100	79.120	76.190	Bowman et al., 1990; revision of BM-1753
BM-1803	caribou bone	Thule	870 ± 30	75.390	97.290	McGhee, 1984 (19)
BM-1803R	caribou bone	Thule	1160 ± 100	75.390	97.290	Bowman et al. 1990; revision of BM-1803
BM-1804	caribou bone	Thule	800 ± 30	75.390	97.290	McGhee, 1984 (19)
BM-1804R	caribou bone	Thule	1100 ± 100	75.390	97.290	Bowman et al., 1990; revision of BM-1804
GaK-1036	caribou bone	Thule	620 ± 80	62.100	74.570	Taillon and Barré. 1987 (20)
GaK-2298	charcoal	Thule	970 ± 90	71.130	157.100	Savelle and McCartney, 1988 (21)
GaK-2749	wood	Thule	810 ± 90	63.680	90.080	Staab, 1979 (22)
GaK-2759	wood	Thule	690 ± 90	63.680	90.080	Staab, 1979 (22)
GSC-650	burned bone, fat	Thule	1330 ± 130	68.475	113.220	Taylor, 1972 (23)[4]
GSC-3098[3]	willow wood	Thule	970 ± 100	78.900	75.608	McCullough, 1989 (3)
GSC-3108	walrus femur	Thule	1200 ± 70	79.120	76.150	Blake, 1988 (3)[4]
GSC-3174[2]	willow wood	Thule	550 ± 60	78.900	75.608	McCullough, 1989 (3)
GSC-3396	plant material	Thule	730 ± 70	79.117	76.150	McCullough, 1989 (3)
GSC-3561	plant material	Thule	590 ± 50	78.900	75.650	McCullough, 1989 (3)
GX-6069	oak wood	Thule	670 ± 110	78.900	75.608	McCullough, 1989 (3)
I-11769	fox bone	Thule	575 ± 75	73.930	99.290	Morrison, 1989 (24)
K-1078	walrus tusk	Thule	1040 ± 100	76.780	70.330	Tauber, 1973 (25)
K-1080	walrus tusk	Thule	1010 ± 100	76.780	70.330	Tauber, 1973 (25)
K-1099	driftwood	Thule	1010 ± 100	76.780	70.330	Tauber, 1973 (25)
K-1487	walrus tusk	Thule	1120 ± 100	78.830	69.250	Tauber, 1973 (39)
K-1488	walrus tusk	Thule	1150 ± 100	78.830	69.250	Tauber, 1973 (39)
M-1260?	charcoal	Thule	1050 ± 110	64.500	161.500	Dumond, 1984 (41)
RL-319	seal bones	Thule	660 ± 90 (500)	66.000	67.000	Schledermann, 1979 (27)
S-477	plant material	Thule	860 ± 90	73.025	80.630	Mary-Rousselière, 1979 (17)
S-516	plant material	Thule	715 ± 60	73.025	80.630	Mary-Rousselière, 1979 (17)
S-882	caribou bone	Thule	850 ± 100	73.025	80.630	Mary-Rousselière, 1976 (17)
S-1320	wood	Thule	1070 ± 70	72.450	93.470	Rick, 1980 (28)
S-1323	wood	Thule	1010 ± 100	72.800	93.600	Rick, 1980 (29)
S-1324	wood	Thule	830 ± 70	72.800	93.600	Rick, 1980 (29)
S-1421	twigs	Thule	1380 ± 90	76.250	92.670	Park, 1989 (30)[4]
S-1545	land mammal bone	Thule	625 ± 60	64.183	83.250	Clark, 1980 (7)
S-1546	land mammal bone	Thule	410 ± 60	64.183	83.250	Clark, 1980 (7)
S-2486	willow	Thule	790 ± 135	63.750	66.420	Stenton, 1983 (31)
SI-2158	seal bone	Thule	1360 ± 90 (1240)	71.130	157.100	Savelle and McCartney, 1988 (21)[4]
SI-3365	moss	Thule	520 ± 110	60.417	64.750	Stewart, 1979 (18)
SI-3377	charcoal	Thule	420 ± 80	59.250	63.750	Fitzhugh, 1994 (15)
SI-3838	wood	Thule	400 ± 60	60.417	64.750	Stewart, 1979; Kaplan, 1983 (18)
SI-3877	wood	Thule	550 ± 60	60.417	64.750	Stewart, 1979 (18)
SI-3878	wood	Thule	400 ± 60	60.417	64.750	Stewart, 1979 (18)
SI-6709	charcoal	Thule	620 ± 50	56.250	61.250	Kaplan, 1985 (43)
Beta-61073	walrus mandible	Thule?	470 ± 60	62.767	65.467	Manley and Jennings, 1996 (32)
BM-1751	walrus radius	RCMP 20th century	155 ± 40	79.120	76.190	Burleigh et al., 1982 (3)
BM-1751R	walrus radius	RCMP 20th century	210 ± 100	79.120	76.190	Bowman et al., 1990; revision of BM-1751

[1] Normalized ages are reported for terrestrial and marine materials; for marine bone the uncorrected age is reported in brackets if that was the reporting protocol of the laboratory; for dates for which no ^{13}C measurement is reported, a value of -15 is assumed. If the correction and normalization protocol was not evident in source literature, dates are listed here as reported. See section on "Normalization and Correction of Ages."

[2] Youngest date on this site.

[3] Oldest dates on this site.

[4] Age adjusted downward on Figure 6.

time. However, the age determinations in the 7500 to 7000 B.P. range suggest that these animals remained in the area, at least seasonally, during the regional marine thermal optimum, when warmth-demanding molluscs, such as the oyster, extended their range into the Gulf of St. Lawrence (Dyke et al., 1996a, their Fig. 27). Walrus occupation of the Bay of Fundy area continued until 7300 B.P. (CAMS-43271) or later.

Canadian Arctic Archipelago: Here too the walrus followed the retreating glacier ice front. The earliest age determination currently available on a walrus from the CAA is on a specimen from Prince Regent Inlet. An isolated tusk partly buried in the gravel of a raised beach at 49.5 m above sea level yielded an uncorrected age of 9470 ± 110 B.P. (S-3081, 9630 ± 110 BP, normalized). Other dates on the raised beach sequence show that this tusk is considerably older than the 49.5 m beach and that it dates very close to time of deglaciation of the site. The two next oldest dated walruses are also from Prince Regent Inlet (S-3086, 9540 ± 100 B.P., normalized; CAMS-38289, 9360 ± 60 B.P.) and date from the interval of local deglaciation. All six samples dating 9000 to 8500 B.P. are from Prince Regent Inlet (3), adjacent eastern Lancaster Sound (1), or eastern Jones Sound (2). These animals postdate local deglaciation but predate deglaciation of the Arctic mainland, Foxe Basin, and Hudson Bay (Dyke and Prest, 1987).

The histogram of radiocarbon ages (Fig. 7) of walruses from the Arctic is multimodal, but has two main clusters: an early Holocene group dating more than 8500 years old and a middle Holocene group dating 3/4000 to 5000 years old, with a particularly strong concentration between 4500 and 5000 years old. Like the early Holocene group, the middle Holocene group is derived mainly from Prince Regent Inlet (7 of 11 samples), but one of the samples (TO-5961; 4750 ± 60 B.P.) is from the northwestern coast of Devon Island, near the present northern limit of the animal. Possibly significant clusters of ages occur between 7500 and 7000 B.P. and between 2000 and 1500 B.P. However, the four samples in the older group are widely distributed between Bathurst Island, near the western limit of the range (I-7795, Harington, 1975), and Prince Regent Inlet, Admiralty Inlet, and Jones Sound (S-3512, -3641, -3527, respectively, Table 1). Two of the seven samples dating 1500 to 2000 B.P. are from East Greenland (K-5980, Lu-3660; Bennike, 1997) and thus probably relate to a different walrus stock. All other arctic walrus dates pertain to the Baffin Bay-CAA stock, including three from West Greenland (K-5978, -5979, Ua-2350; Bennike, 1997).

For this sample size (41 dates, Baffin Bay-CAA only), the probability, from the binomial probability function, that four dates will fall in any one class interval by chance alone is 9.5%; for five dates, it is 3.7%; for six dates, 1.2%; and for seven dates, 0.3%. The two empty class intervals have a probability of 12.2% of being due to chance. The sample provided here is considered to be random because there was no bias in collecting samples from any particular elevation range (all finds were collected) and all material of suitable quality (mainly ivory) has been dated. Hence, the calculated probabilities are meaningful.

The distribution of walrus age determinations into two main clusters strongly resembles the distribution of age determinations on bowhead whales from the CAA (Dyke et al., 1996b). This similarity suggests that the spatial distribution and abundance of both species were controlled by common environmental factors. For the bowhead whale, Dyke et al. (1996b) argued that the critical factor was the extent of summer sea-ice clearance. This is also the most probable explanation of changes in walrus ranges. Other paleoenvironmental records from the CAA are discussed by Dyke et al. (1996a, b).

THE ARCHAEOLOGICAL RECORD

Walruses form an important part of modern Inuit subsistence economies. Traditional ethnographic sources (e.g., Boas, 1888; Murdock, 1892; Birket-Smith, 1924; Mathiassen, 1928; various papers in Damas, 1984) and recent oral historical documentation (e.g., Freeman, 1976; Riewe, 1992) attest to their importance in the diet of early historic Inuit as well. These accounts indicate that walruses were harvested when abundance and local physical conditions and technology permitted. Accordingly, prehistoric archaeological sites in the Arctic may provide proxy evidence for walrus range expansion and contraction and for temporal changes in relative abundance that complements the fossil evidence discussed above.

Two major cultural complexes are recognized in the Canadian Arctic and Greenland: Paleoeskimo and Neoeskimo. These are summarized in detail in Maxwell (1985), McGhee (1978, 1996) and Schledermann (1996). Paleoeskimo incorporates Independence I (ca. 4000 to 3700 B.P.), Pre-Dorset (ca. 3700 to 2500 B.P.), Sarqaq (ca. 3500 to 2500 B.P.), Independence II (ca. 3000 to 2500 B.P.), Groswater Dorset (ca. 2800 to 2000 B.P.), and Dorset (ca. 2500 to 1000 B.P.) cultures. Neoeskimo incorporates prehistoric Thule (ca. 1000 to 400 B.P.) and later derivative historic and modern Inuit. In addition, southwestern Greenland was inhabited by Norse colonies for approximately 500 years from about A.D. 985 (see e.g., Jones, 1964). Note that while walrus remains are found throughout Norse Western and Eastern Settlement sites, most apparently resulted from hunting expeditions farther north in the *Nordrsetur* region (Disko Island and vicinity). A discussion of these remains and their social and economic context is given in McGovern (1985) and McGovern et al. (1996), and they are not further dealt with here.

General Distribution of Walrus Remains in Archaeological Sites

Prehistoric sites or site components from which walrus remains have been recovered and for which radiocarbon dates are available are listed in Tables 3 and 4 and located on Figure 2. These remains occur temporally throughout the Paleoeskimo and Neoeskimo sequence and geographically throughout most of the historic walrus distribution range. In addition, they occur in a few Maritime Archaic and later Indian sites, including, for example, the L'anse Amour site on the Strait of Belle Isle coast of Labrador, where an unmodified walrus tusk was recovered from a burial dated on charcoal to 7530 ± 140 B.P. (I-8088; Tuck,

1977). Walrus remains have also been recovered from a Maritime Archaic Indian culture site on the central Labrador coast dated 4650 ± 60 B.P. (SI-2146, Fitzhugh, 1978). The southernmost remains are from a Woodland Indian culture site on the Bay of Fundy shore of New Brunswick, dated at 1880 ± 80 B.P. (Y-1291; Wilmeth, 1978; Stewart, 1974). A Groswater Dorset site at Port au Choix, Newfoundland, dated at 2540 ± 160 B.P. (Beta-49759), also yielded walrus remains (Renouf, 1994). The general absence of their remains in other Indian culture sites from southeastern Canada suggests that walruses were not exploited significantly in that area in prehistoric times. References to large historic walrus herds in this region mainly concern the Magdalen Islands and Sable Island; therefore, Sable Island, at least, may have remained inaccessible to prehistoric occupants of the mainland.

Outside of the historic walrus range, a walrus ivory artifact was recovered from the Namu (Indian) site on the central British Columbia coast (Fig. 2) from a level dated to 4540 ± 140 B.P. (Fladmark, 1975). This site is far south of the historic, and probable contemporary, range of the Pacific walrus, and no walrus remains occur here in diet-related contexts (Cannon, 1991). Accordingly, the artifact very likely represents long-distance trade in, or at least acquisition of, walrus ivory, such as has been recorded in medieval Europe (Møhl, 1974). This would also seem to be the only plausible explanation of an even more remote find: the anterior part of a walrus cranium lacking tusks that was recovered from a site on Mackinac Island, Michigan, reportedly from a beach deposit, yielded an age of 975 ± 60 B.P. (Beta-27515 [ETH-4584], Table 3). A human-worked walrus baculum (as yet undated), apparently from an archaeological context near Gaylord, Michigan, is presumably of similar age. These specimens, along with the bones of a sperm whale, a probable bowhead whale, and a fin whale from three counties of Michigan, once suggested the possibility of a postglacial marine invasion of the Lake Michigan basin. However, the ages of these whale bones have been determined to be >190 B.P. (I-11638), 750 ± 60 B.P. (GSC-2428), and 720 ± 70 B.P. (GSC-2464), respectively, suggesting the far-inland acquisition by late prehistoric Indians of a variety of marine mammal materials, in addition to walrus (Harington, 1988).

Other walrus specimens from inland sites in eastern North America are perhaps similar in nature to the aforementioned Michigan finds. These include two tusk implements excavated at Brewerton, New York; a baculum war club found near Rochester, New York; an incised tusk from the Atwell site, a 16th century Onondoga Iroquois site southeast of Syracuse, New York; and a piece of tusk from the Thompson Island site, Quebec (Harington, 1988: 238). All of these sites are south of the area shown in Figure 2.

A probable walrus bone dated to 4280 ± 200 B.P. (RIDDL-320; Cinq-Mars, 1991) from the Engigstciak site in northern Yukon Territory, and the walrus remains (2 out of 5902 identified specimens; Taylor, 1972) from the early

Thule Lady Franklin Point site on southwestern Victoria Island, probably represent extralimital Pacific walruses.

While the above data indicate that walrus remains occur throughout the prehistoric human occupation sequence in the Arctic and maritime Subarctic, there are long intervals, particularly 3400 to 2600 B.P. and 2200 to 1200 B.P., for which few if any remains are reported from the High Arctic (Fig. 8). The latter period corresponds to the Middle Dorset abandonment of the High Arctic (see below) and the earlier period may represent a similar event during the middle Pre-Dorset.

Archaeological Context of Walrus Remains

A fuller evaluation of these walrus remains requires consideration of their archaeological contexts and relative abundances. Relative and absolute abundances of walrus remains at representative coastal sites within the historic walrus distribution range for which we have appropriate data are listed in Table 5. Note that the table includes some sites or components for which radiocarbon dates have not been reported but for which the cultural affiliation, hence age, is reasonably well established. Also, in some instances, faunal totals from adjacent sites or components of similar cultural affiliation have been combined. Finally, unless noted otherwise, the tables indicate walrus remains in a diet, as opposed to artifactual, context.

It is acknowledged that the sites or components are limited in number and geographically widespread, that the respective occupations may represent differing components of their respective settlement systems, and that the sites may have been influenced by potentially different taphonomic processes. However, although walrus rarely constitutes the dominant faunal material at these sites (caribou or ringed seal typically dominate; see e.g., the summary tables in Savelle and McCartney, 1988; Savelle, 1994), several potentially instructive observations can be made.

First, walrus remains are rare in the early part of the Paleoeskimo sequence (ca. 4000 to 2500 B.P., including Independence I, Sarqaq, Pre-Dorset, Independence II, and "transitional"). Of the faunal samples from 21 sites or components, six lack walrus remains, a seventh is a single weathered tooth, and the walrus remains associated with five others are ivory debitage, and are thus more properly considered artifact debris than subsistence-related debris. Of the remaining nine samples, one consists of 18 "unidentified large sea mammal bones" that may not even be walrus, and four consist of a mixture of debitage (26 specimens) and diet-related material (10 specimens). Thus, out of a total early Paleoeskimo faunal sample of 72 949 identified specimens, a maximum of 268 (0.36%) can be referred to as "diet-related" walrus bone. Accordingly, there is little evidence to suggest that early Paleoeskimos incorporated walrus importantly, or at all, in their diet. Although the fossil record indicates a low or declining relative walrus abundance in the Canadian High Arctic during early Paleoeskimo time (ca. 4000 to 2500 B.P.), the

TABLE 4. Previously unpublished radiocarbon dates on walrus tusks from archaeological sites in northwestern Foxe Basin; sites excavated by Dr. Jørgen Meldgaard, National Museum, Copenhagen, Denmark; published with his permission. Notes on samples filed with Canadian Museum of Civilization (R. Morlan, pers. comm., 1998).

Lab Number	Site[1]	Context	Elevation	Age[2]
K-1077	Lyon Hill	Sarqaq	41	3700 ± 120
K-1040	Parry Hill	Sarqaq, Early	46	3880 ± 130
K-1041	Parry Hill	Sarqaq, Early	49	3920 ± 130
K-1042	Jens Munk	Sarqaq, Middle	44	3250 ± 120
K-1073	Freuchen	Sarqaq, Middle	21	2760 ± 110
K-1043	Jens Munk	Sarqaq, Late	24	2880 ± 120
K-1076	Tikilik	Sarqaq, Late	23	2620 ± 110
K-1074	Tikilik	Sarqaq, Late	23	2910 ± 100
K-1075	Freuchen	Sarqaq, Late	25	2660 ± 100
K-1046	Alarnerk	Dorset	11	1240 ± 100
K-1047	Alarnerk	Dorset	14	1810 ± 110
K-1067	Abverdjar	Dorset	8	1240 ± 100
K-1068	Abverdjar	Dorset	8 – 10.5	1490 ± 100
K-1048	Alarnerk	Dorset, Early	19	2110 ± 120
K-1069	Tikilik	Dorset, Early	18	2370 ± 110
K-1070	Tikilik	Dorset, Early	18	2460 ± 110
K-1071	Freuchen	Dorset, Early	18.5	2380 ± 110
K-1072	Tikilik	Dorset, Early	19	2570 ± 110
K-1044	Kaersut	Dorset, Late	6.5	1100 ± 100
K-1045	Alarnerk	Dorset, Late	6.5	1170 ± 100

[1] Coordinates not supplied in source notes. Parry Hill, 69°23′19″N, 81°47′54″W; Lyon Hill, 69°22′37″N, 81°48′34″W; Freuchen, 69°20′48″N, 81°48′23″W; Tikilik, 69°21′34″N, 81°54′53″W; Jens Munk, 69°34′N, 80°18′W; Kaersut, 69°28′N, 80°19′W; Alarnerk, 69°12′N, 81°20′W; Abverdjar, 69°25′N, 82°20′30″W.

[2] Ages not corrected for isotopic fractionation. These ages can be conventionally normalized by adding 160 years.
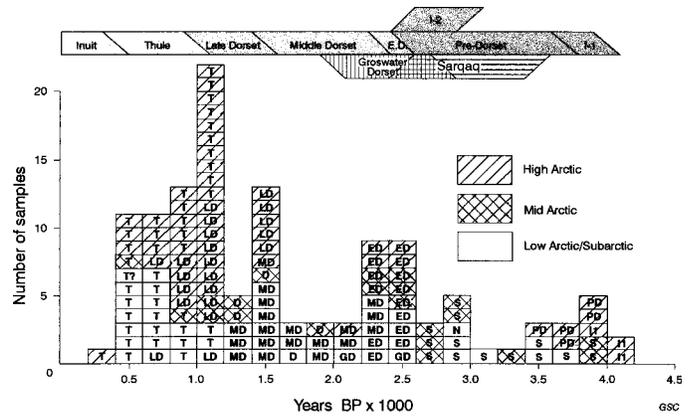

FIG. 8. Frequency distribution of radiocarbon dates on archaeological sites reporting walrus remains. The age ranges of Neoeskimo and Paleoeskimo cultures are displayed at the top. Radiocarbon dates that are within one class interval (200 years) of these ranges were plotted as reported. Maximum limiting dates on a cultural interval (e.g., on driftwood or on sea mammal bones or fat) were adjusted downward, generally by one class interval, if they did not fall within the age ranges indicated at the top. Two seemingly anomalous dates (UQ-88 and SI-2990) were not plotted.

paucity of "diet-related" walrus remains throughout the occupation period and area suggests technological restrictions relating to the harvesting of these animals. In this regard, McCartney (1989) has suggested that the lack of walrus remains at early Paleoeskimo sites may be related to the lack of appropriate watercraft. The few remains that are present may represent scavenging.

The later Paleoeskimo period (Early to Late Dorset; ca. 2500 to 1000 B.P.) contrasts strongly with the earlier one. Walrus remains in sites of this age are relatively common and occur in definite "diet-related" contexts. This change probably represents the development of a relatively sophisticated walrus harvesting technology. This development broadly coincides with an increase in walrus in the fossil record. Although the small fossil sample and uncertain reservoir age corrections prevent further "fine-tuning" of the variability in relative walrus abundance at this time, the archaeological record is more informative. Walrus remains tend to be far more common in Early Dorset (ca. 2500 to 2300 B.P.) and Late Dorset (ca. 1500 to 1000 B.P.) periods than in the Middle Dorset period (ca. 2300 to 1500 B.P.). Indeed, most of the High Arctic was abandoned by Paleoeskimos during the Middle Dorset period, and the cooling trend that has been inferred from this may

have affected walrus abundance (see e.g., McGhee, 1976; Maxwell, 1985; Fig. 8). Of the Middle Dorset sites listed in Tables 3, 4, and 5, only Saatut (site 12) lies north of Hudson Strait, and it is marginally within the High Arctic ecoclimatic region. However, the best independent paleoclimate records from the High Arctic, the ice-core records, do not show a distinctly cold interval at this time (Paterson et al., 1977; Koerner and Fisher, 1990; Fisher et al., 1995). Indeed, the Meighen Ice Cap record indicates a long period of negative mass balance (warm summers) throughout the interval from 2500/2000 to 660 B.P. (Koerner and Paterson, 1974).

A major exception to the above trend is the Middle Dorset site of Avayalik-1 in northern Labrador, where 35.1% of the 1696 identified faunal specimens are walrus (Jordan, 1980). Unlike the High Arctic, the Middle Dorset period was a time of maximum Dorset occupation in this region (Fitzhugh, 1980), and local conditions may have been exceptionally favourable for walrus.

Finally, the abundance of walrus remains at Thule sites (ca. 1000 to 400 B.P.) shows considerable variation, but given the difficulties in establishing Thule chronologies (e.g., Morrison, 1989), no attempt is made here to treat the sequence according to temporal subdivisions. However, a decline in bowhead whaling, the Thule Eskimo abandonment of the High Arctic, and changes in Thule settlement patterns elsewhere beginning ca. 400 B.P. have all been attributed to changes in faunal resource abundance and distribution due to the Little Ice Age (ca. 6/400 to 100 B.P.; see summaries in McGhee, 1978; Maxwell, 1985). Since this period is as yet unrepresented by fossil walrus remains, a detailed consideration of archaeological walrus remains within a chronologically controlled framework (beyond the scope of the present paper) would presumably shed some light on the response of the walrus to changing environmental conditions associated with the Little Ice Age.

TABLE 5. Frequency of walrus remains from archaeological sites in the Canadian Arctic. In the number of identified specimens (NISP), large cetacean (primarily bowhead whale) remains have been excluded in determining total sample sizes.

Site or Component	Site No. (Fig. 2)	Cultural Affiliation	NISP Walrus/Total	Percent Walrus	Reference
Cold	35	Independence I	0/1139	0	McGhee, 1979
Upper Beaches	35	Independence I	0/112	0	McGhee, 1979
Tusk	3	Independence I	6/12[1]	50	Schledermann, 1990
Bight	3	Sarqaq	0/2724	0	Schledermann, 1990
Qajaa	44	Sarqaq	0/15151	0	Møhl, 1997
Nipisat	45	Sarqaq	232/28233	0.8	Gotfredsen, 1998
Itivnera	38	Sarqaq	0/6450	0	Møhl, 1972
Gull Cliff	35	Pre-Dorset	18/817[2]	2.2	McGhee, 1979
Ridge	3	Pre-Dorset	2/394[1]	0.5	Schledermann, 1990
Back Bay	37	Pre-Dorset	0/414	0	Ramsden and Murray, 1995
Igloolik NiHf-58	26	Pre-Dorset	14/566[3]	2.5	Murray, 1997
Igloolik NiHf-2	26	Pre-Dorset	11/291[3]	3.8	Murray, 1997
Icebreaker Beach	4	Early Pre-Dorset	8/10885[4]	0.01	McCartney, 1989
Icy Bay	4	Early Pre-Dorset	3/1205	0.2	McCartney, 1989
Icy Bay	4	Middle Pre-Dorset	3/529[4]	0.6	McCartney, 1989
Hind	4	Middle Pre-Dorset	2/1566	0.1	McCartney, 1989
Field School	4	Middle Pre-Dorset	6/689	0.9	McCartney, 1989
Twin Ponds	4	Middle Pre-Dorset	2/1213[4]	0.2	McCartney, 1989
Rocky Point	4	Late Pre-Dorset	12/559[4]	2.1	McCartney, 1989
Grave	3	"Transitional"	1/7	14.3	Schledermann, 1990
Lower Beaches	35	Independence II	1/1432[5]	0.06	McGhee, 1981
Baculum	3	Early Dorset	72/359	20.05	Schledermann, 1990
Tusk	3	Early Dorset	0/9	0	Schledermann, 1990
Shell	3	Early Dorset	6/1064	0.6	Schledermann, 1990
Karluk Island	11	Early Dorset	292/2074[3]	14.1	Helmer, 1981
Markham Point	11	Early Dorset	37/573[3]	6.5	Helmer, 1981
Nunguvik	17	Early Dorset	249/1861	13.4	Mary-Rousselière, 1976
Igloolik NiHf-47	26	Early Dorset	81/310[3]	26.1	Murray, 1997
T-1	7	Early Dorset	438/3873	11.3	Cox and Spiess, 1980
Tyara	9	Early Dorset	445/2402	18.5	Taylor, 1968
Saatut	12	Middle Dorset	6/15736	0.04	Mary-Rousselière, 1976
Koliktalik-1	16	Middle Dorset	31/5315	0.6	Cox and Spiess, 1980
Akulialuk	33	Middle Dorset	3/618	0.5	Cox and Spiess, 1980
Avayalik-1	15	Middle Dorset	596/1696	35.1	Cox and Spiess, 1980
Longhouse	3	Late Dorset	52/1602	3.2	Schledermann, 1990
Shelter	3	Late Dorset	2/93	2.2	Schledermann, 1990
Narrows	3	Late Dorset	4/186	2.2	Schledermann, 1990
Cove	3	Late Dorset	30/1426	2.1	Schledermann, 1990
Old Squaw	3	Late Dorset	8/30	26.7	Schledermann, 1990
Franklin Pierce	3	Late Dorset	11/50	22	Schledermann, 1990
Karluk Island	11	Late Dorset	127/9311[3]	1.4	Helmer, 1981
Markham Point	11	Late Dorset	4/112[3]	3.6	Helmer, 1981
Tasiarulik	11	Late Dorset	332/5116[3]	6.5	Darwent, 1995
Diana Bay	14	Late Dorset	44/636	6.9	Julien, 1980
Nunguvik	17	Late Dorset	50/788	6.3	Mary-Rousselière, 1976
Igloolik NiHf-45	26	Late Dorset	103/2775	3.7	Murray, 1997
Igloolik NiHf-4	26	Late Dorset	100/1027	9.7	Murray, 1997
Nunguvik	17	'Early' Thule	164/3263	5.02	Mary-Rousselière, 1976
E Ellesmere	3	Thule	1097/15630	7	McCullough, 1989
Porden Point	30	Thule	1/933	0.1	Park, 1983
Porden Point	30	Thule	45/10 783	0.4	Park, 1989
Learmonth	29	Thule	113/3373	3.4	Taylor and McGhee, 1979
Learmonth	29	Thule	4/1489	0.3	Rick, 1980
Cape Garry	28	Thule	1/2862	0.03	Rick, 1980
Hazard Inlet	34	Thule	1/9434	0.01	Whitridge, 1992
Cumberland Sound	27	Thule[6]	0/3706	0	Schledermann, 1975
Peale Point	31	Thule	43/9448	0.5	Stenton, 1983
Talaguak	36	Thule[7]	138/4045	3.4	Sabo, 1981
Silumuit	22	Thule	706/18318	3.9	Staab, 1979
Illorpaat	46	Thule	0/73376	0	Gulløv, 1997
Nugarasuk	47	Thule	24/26999	0.1	Møhl, 1979
Nunguvik	17	'Late' Thule	113/837	13.5	Mary-Rousselière, 1976

[1] Materials occur as ivory "chips"

[2] Described as "unidentified large sea mammal bone"

[3] Total NISP calculated from percentages

[4] Material occurs as both manufacturing debris and diet-related remains

[5] "Single weathered tooth"

[6] Excludes upper layers with European contact material

[7] Includes "classic" and "developed" Thule

The above consideration of archaeological remains relating to walrus is necessarily general, and many factors may have influenced the distribution and abundance of these walrus remains. Nevertheless, this "coarse-grained" analysis augments interpretation of the geological walrus record and helps in "fine-tuning" periods of walrus abundance and depletion beyond what is possible with radiocarbon dating. By corollary, the fossil record provides a background from which to examine and model changes in prehistoric subsistence systems.

SUMMARY AND DISCUSSION

The Pacific walrus lacks a documented Late Wisconsinan and early Holocene record in North America. The contrasting abundance of finds of Atlantic walruses of that age calls into question the existence of a Pacific walrus refugium at LGM in the eastern Pacific Ocean. We hypothesize that its refugium was along the south coast of Beringia and in the adjacent northwestern Pacific Ocean.

The Atlantic walrus evidently invaded newly deglaciated coastal areas of North America northward from its LGM refugium at the earliest possible times. Its northern limit advanced from the vicinity of the glacial limit (Long Island, New York) ca. 18 000 B.P. to the Bay of Fundy by 12 700 B.P., the Grand Banks by 12 500 B.P., southern Labrador by 11 500 B.P., and the central CAA by 9700 B.P. Meanwhile, its southern limit retracted from about latitude 33°N, where undated specimens of probable LGM age have been collected (Harington and Beard, 1992), to the Bay of Fundy (43°N) by ca. 7500 B.P. Further precision of this range retraction can be provided only by dating additional specimens dredged from the American and Canadian continental shelves. Although further dating of specimens is also necessary to establish a secure record for southeastern Canadian waters, these appear to have been occupied continuously by walrus throughout postglacial time, even during the marine thermal optimum, when sea surface temperatures increased sufficiently to allow entry and persistence of oysters and other thermophilic species.

The rapid exploitation of new territory by walruses during deglaciation and the manyfold expansion of their total area of occupation starkly contrast with their evident present inability to reoccupy territory from which they have been extirpated, as well as with the apparently limited present movement of animals between putative regional stocks (Born et al., 1995). It is likely that the present situation reflects low population pressures on food resources within the current remnant stock areas and continued hunting pressures, rather than a limitation of present ranges by molluscan food resources or by water temperature and sea-ice conditions.

Walrus remains in raised marine, or at least in littoral, deposits have a lower preservation potential than do remains of the larger and more buoyant bowhead whale. The walrus, therefore, leaves a much poorer fossil record of

range extensions and retractions. Nevertheless, remains are sufficiently abundant that the interval of occupation, the range limits, and the relative abundance, both spatial and temporal, can be defined reasonably well in the CAA. Except possibly for those in the Gulf of Boothia, no remains have yet been found beyond the historic range limits. Remains dating 9700 to 8500 B.P. and 5000 to 3/4000 B.P. are most common. The similarity of this chronological record to that of the bowhead whale in the same region strongly suggests that the Holocene fluctuations of environmental conditions affected both species. Thus, a broad controlling mechanism, such as the seasonal sea-ice clearance pattern, is inferred, rather than more species-particular mechanisms, such as changes of food resources or incidence of diseases.

Geographic gradients in abundance of walrus remains within the CAA seem largely explicable in terms of the influence of wintering polynyas on seasonal migration patterns. For example, the increase in abundance of remains southward along Prince Regent Inlet may illustrate the effect of the Fury and Hecla Strait polynyas. There seems, therefore, to be potential in using walrus remains in raised marine deposits to extract the histories of the major polynyas. In light of the abundance of archaeological sites around these polynyas (Schledermann, 1981; 1996; McGhee, 1984), this history might be useful in explaining site occupation and abandonment or technological changes.

Taken alone, walrus remains are risky indicators (about 60% reliable) of paleo–sea level. Complete or nearly complete skeletons are those most *unlikely* to represent a former shoreline site. Most of the more complete skeletons currently documented in the CAA represent animals that apparently expired while crawling inland, and the same explanation is suggested for the otherwise enigmatic Moncton walrus. While the interpretation of remains found far inland and above the postglacial marine limit is self-evident, remains of animals that crawled onto elevated strandlines and died are not readily distinguished from those that died on their contemporaneous beaches or that rafted ashore on sea ice. Extent of burial of remains is of little help because burial in a beach by periglacial processes is indistinguishable from periglacial modification of a beach deposit that contains isolated bones.

Although walrus remains occur at arctic archaeological sites throughout the period of occupation, they are exceedingly rare at sites older than Early Dorset, and they may not have been harvested by early Paleoeskimos. Subsequent variations in the relative abundances of walrus remains at Dorset and Thule sites and in the distribution of these sites may be related to changes in the coastal sea-ice environment (see e.g., Murray, 1997). Further zooarchaeological studies should yield paleoenvironmental reconstructions, particularly of sea-ice conditions, at finer chronological resolutions than currently possible using geological data alone. However, as yet it is not possible to demonstrate a meaningful correlation between major cultural events, such as Middle Dorset abandonment of the High Arctic,

and regional paleofaunal or paleoclimate records. Indeed, the correlations between cultural and paleoclimate sequences in the Canadian Arctic in general remain exceedingly tenuous, in part because of the insecurely dated and interpreted proxy climate records (e.g., Williams and Bradley, 1985; Jacobs, 1985; Barry et al., 1977; Bradley, 1990). Meanwhile, Holocene faunal histories from the Canadian Arctic have been presented for only two sea mammals (Dyke et al., 1996b; this paper) and for no land mammals.

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