Polar Research

Late Pleistocene fossil find in Svalbard: the oldest remains of a polar bear (*Ursus maritimus* Phipps, 1744) ever discovered

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Abstract

During recent fieldwork in Svalbard, a well preserved subfossil left mandible of a polar bear (*Ursus maritimus* Phipps, 1774) was discovered. A ^{14}C age determination shows that it is older than 45 Ky (kilo-years), and an age determination with infrared-stimulated luminescence—together with the stratigraphic position of the bone—suggests that it is of Eemian–Early Weichselian age: 130–110 Ky old. This makes the find the oldest remains of a polar bear ever discovered. Morphological analyses of the mandible suggest that it comes from a fully grown male that was similar in size to extant male polar bears. The comparative study of other available subfossil polar bear remains did not reveal any significant change in size of polar bears during the Late Quaternary.

The polar bear (*Ursus maritimus* Phipps, 1774) is the largest of the four extant bear species of the genus *Ursus*, the other three species being the brown bear (*Ursus arctos* L., 1758), the American black bear (*Ursus americanus* Pallas, 1780) and the Asiatic black bear (*Ursus thibetanus* Cuvier, 1823) (Nowak 1999; Wozencraft 2005). The polar bear is closely related to the brown bear, and fertile hybrids between the species are well known from zoos (Gray 1972). Recently a polar bear–brown bear hybrid was shot in the wild in the Canadian Arctic (National Geographic News 2006). Based on the dental characteristics of the polar bear, Thenius (1953) concluded that a relatively late descent from the brown bear was probable, and pointed out that the close relationship between polar bears and brown bears is corroborated by the two species being able to produce fertile hybrids. Kurtén (1964) concluded that polar bears probably branched off from brown bears that became isolated on Siberian coastal enclaves some time during the mid-Pleistocene, 800–130 Kya (kilo-years ago), and with time became increasingly specialized carnivores that hunted on the pack ice. This conclusion has been supported by genetic studies on the relationship between living brown bears on the Alexander Archipelago, Alaska, and polar bears (Heaton et al. 1996). Today, polar bears have a circumpolar distribution, and the southern limit of their range is primarily determined by the distribution of pack ice and landfast annual ice during the winter (DeMaster & Stirling 1981; Amstrup 2003).

The fossil record of the polar bear is very poor (Kurtén 1964; Harington 2008; Laidre et al. 2008), and its evolutionary history is not well known. In light of the scarcity of polar bear fossils, every new find is of interest. This paper reports on the find of an Eemian–Early Weichselian (130–110 Kya) left mandible from the Poolepynten coastal cliffs (78°27′N, 11°44′E), Prins Karls Forland, Svalbard (Fig. 1), identified to be from a polar bear.

Stratigraphy of the Poolepynten sections

Bergsten et al. (1998) and Anderson et al. (1999) studied the stratigraphy, depositional history and environmental development of the Poolepynten coastal cliffs (Fig. 2). Anderson et al. (1999) recognized a sequence of two different marine units, which they labelled units A and C. The marine units A and C are separated by a thick till complex, unit B, composed of both subglacially deposited lodgement till (unit B1) and a chaotic component of pushed, as well as slumped and reworked, glacial sediments (unit B2). The cliff section is capped by littoral gravels, unit D, separated from the underlying units by an erosional unconformity and a boulder lag.

The lowermost unit A is characterized by stratified fine-to-medium sand, and its marine origin is manifested in kelp horizons and in the random occurrence of subfossil molluscs. Outsized pebbles and cobbles occur randomly in the unit, suggesting rafting by sea ice, glacial ice or kelp

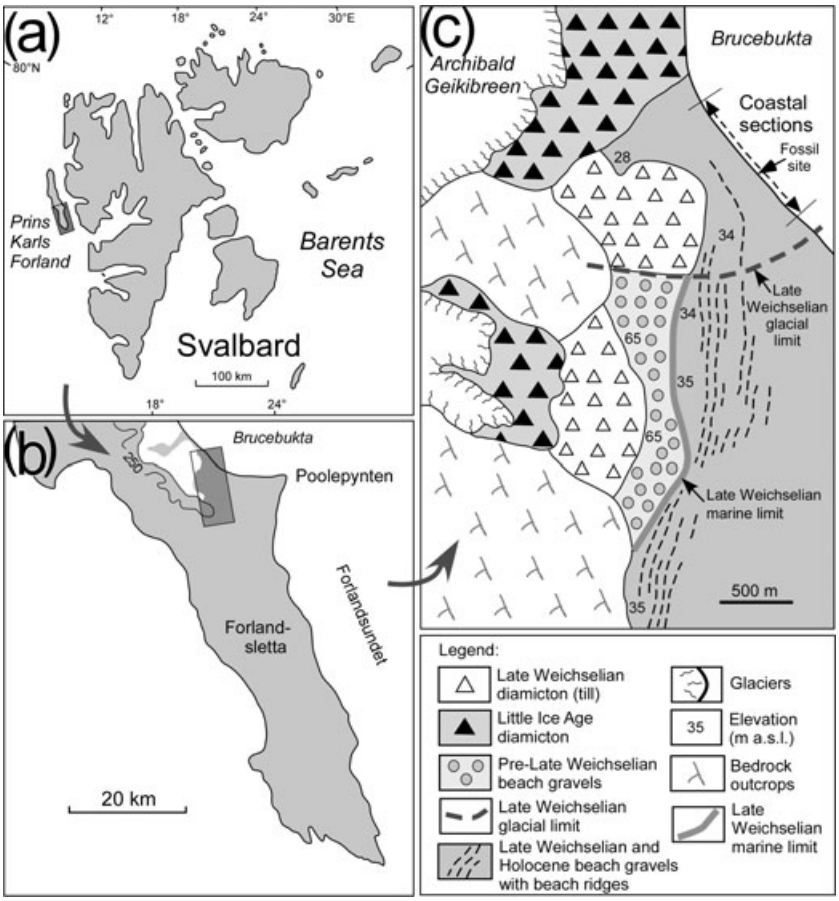

Fig. 1 (a) Prins Karls Forland, the westernmost island in the Svalbard Archipelago. (b) Poolepynten, in central–southern Prins Karls Forland. (c) Simplified map of surface deposits landwards of the Poolepynten sections. Modified from Anderson et al. (1999).

during the deposition of the unit. It is interpreted as a prodelta formation, deposited from sediment gravity flows in a nearshore, shallow marine environment (Fig. 2b). The subfossil mollusc fauna of unit A contains four bivalve species, which are well preserved and occur in a living position in the sediment (Anderson et al. 1999). All species currently occur on Svalbard. A detailed study of the foraminiferal stratigraphy by Bergsten et al. (1998) shows that unit A contains an abundant and diversified foraminiferal fauna, dominated by Arctic species, but also with a number of Boreal and Boreal–Arctic species being present. Bergsten et al. (1998) concluded that the foraminifera fauna of unit A is similar to modern fauna in shallow sites in Svalbard, and that the fauna reflects an Arctic, open-marine environment, influenced by glacier input and advection of warm North Atlantic water. A ^{14}C date on kelp yielded an infinite age of >49 Ky, and a sediment sample dated by the infrared-stimulated luminescence (IRSL) method gave an age envelope of 80–150 Ky. Bergsten et al. (1998) and Anderson et al. (1999) argued that unit A might be of last interglacial (Eemian) to Early Weichselian age.

The upper marine unit C constitutes the bulk of the western part of the cliffs (Fig. 2a). Its marine origin is confirmed by numerous (>70) kelp layers and in situ marine molluscs. It is interpreted as a prodelta formation, deposited from sediment gravity flows/turbidites in a nearshore marine environment (Fig. 2b). The mollusc and foraminifera fauna indicate nearshore marine conditions similar to those of today. Two ^{14}C dates from marine kelp gave infinite ages (>41 and >49 Ky), and an IRSL date of the sediments provided an age envelope of 40–70 Ky.

The geometry of the till complex, unit B, is interpreted to define a glacier-eroded basin, where unit A has been removed from the western part of the basin, and where unit C was deposited subsequently to the deposition of unit B (Fig. 2a). Subunit B1, the lodgement till, is a massive matrix-supported silty/clayey diamicton, containing numerous subangular, striated and bullet-shaped stones and boulders of local provenance. A clast fabric analysis showed strong preferred clast orientation, indicating ice movement from the west. The contact with the underlying unit A is partly sharp, and partly diffuse, and has been deformed by a glacial push. A well-developed drag fold, signifying a glacial push from the west, was observed in unit A, just below the lower contact with unit B1. Subunit B2 is composed of diamicton, ranging from

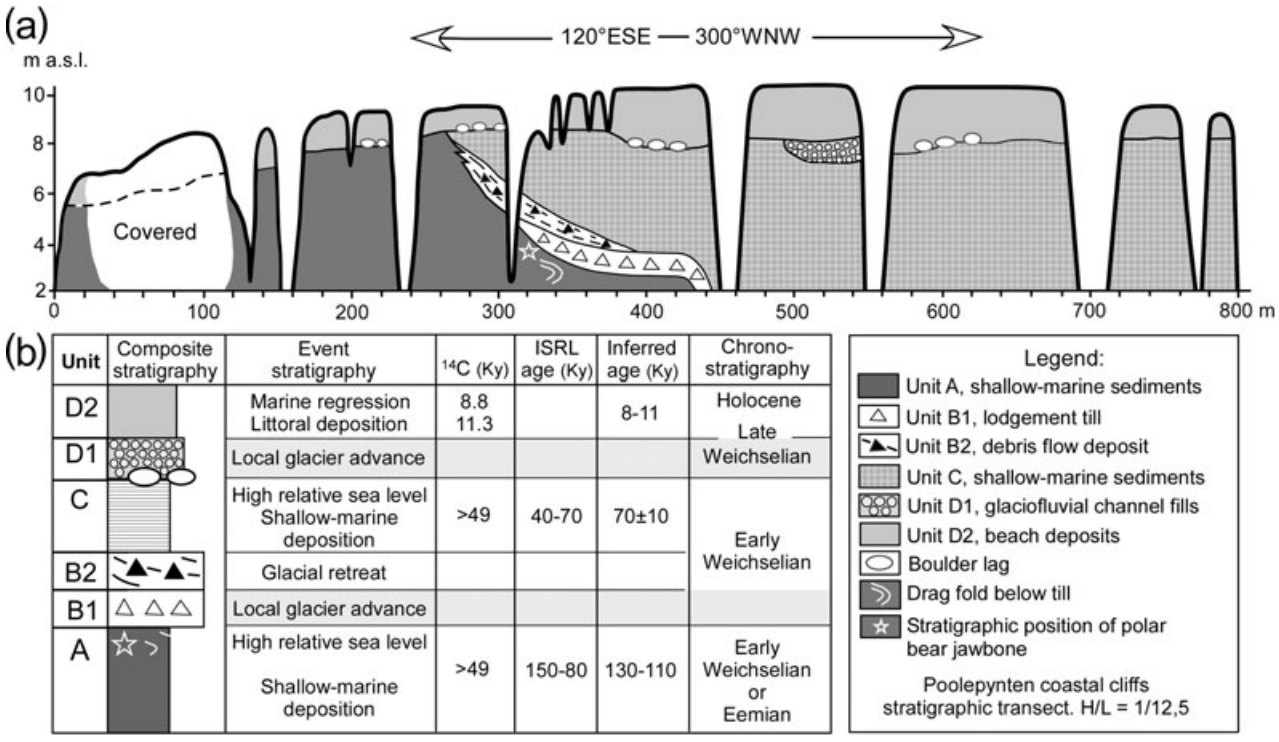

Fig. 2 (a) Schematic presentation of the general stratigraphy in the Poolepynten coastal sections. (b) Composite log for the stratigraphy of the Poolepynten coastal site sediments, inferred depositional environments, events and ages. Modified from Anderson et al. (1999). The star indicates the stratigraphic position of the polar bear mandible.

stratified to massive, and poorly sorted sandy gravel; its lower contact with unit A is either sharp and erosive or diffuse (Fig. 2a). The sediments of subunit B2 are interpreted as subaquatic redeposition of the B1 till by slumping (Fig. 2b). There is no absolute age control on unit B, but it is younger than the underlying unit A and older than the overlying unit C, and consequently has a proposed age of 70–80 Ky (Fig. 2b).

The mandible (Fig. 3) was discovered at ca. 320 m in the section transect, about 3.5 m a.s.l. (Fig. 2a). It was embedded in a heavily glaciotectonically deformed section of unit A, close to the drag fold below the contact with unit B.

Dating of the polar bear mandible

The mandible was dated by accelerator mass spectrometry (AMS) ^{14}C age determination on a sample (about 50 mg) drilled out from the canine tooth at the Lund University Dating Laboratory, Sweden. It was dated to be older than 45 Ky (sample LuS-6155; Table 1).

Measurements of the polar bear mandible

In accordance with von den Driesch (1976), the following five measurements of the mandible were taken: (1)

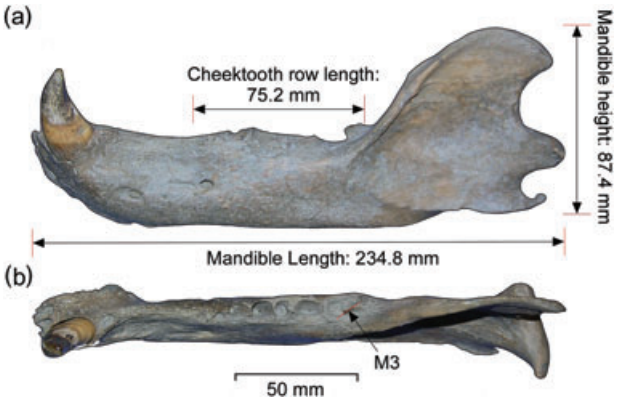

Fig. 3 The Poolepynten polar bear mandible. (a) Lateral view. (b) Dorsal view.

mandible length (measured from the infradentale to the midpoint of the condyle process); (2) mandible height (measured from the basal point of the angular process to the coronion); (3) cheek tooth-row length (measured from the anterior margin of the P_4 alveolus to the posterior margin of the M_3 alveolus); (4) length of M_3 alveolus; (5) breadth of M_3 alveolus.

For comparison, the same measurements were taken on 55 (25 females and 30 males) mandibles from adult

Table 1 Subfossil polar bear (*Ursus maritimus*) specimens and their reported ages.

Fossil find, location	Age determination (Ky)	Lab. no.	Inferred age (Ky)	References
Kolnæs, Greenland	440 ± 45	K-352		Bennike (1991)
North-eastern Greenland	820 ± 60	AAR-1776		Andreasen (1997)
Washington Land, Greenland	960 ± 60	AAR-5775		Bennike (2002)
Washington Land, Greenland	1415 ± 60	AAR-5774		Bennike (2002)
Arctic Canada	1510 ± 30	CAMS-66368		Unpubl. data, Art Dyke, pers. comm. 2006
Victoria Island, Nunavut, Canada	1560 ± 65	Gif-7512		Harington (2003)
	1350 ± 40	Gif-8434		
	1310 ± 40	Gif-8178		
Brønlund Fjord, Greenland	1520 ± 110	AAR-1357		Bennike (1997)
Prince of Wales Island, Nunavut, Canada	2135 ± 120	Beta-18129		Harington (2003)
Sønderland, Greenland	3320 ± 85	K-5928		Rasmussen (1996)
Sønderland, Greenland	3470 ± 85	K-5930		Rasmussen (1996)
Nuulliit, Thule, Greenland	5060 ± 95	K-2560		Grønnow & Jensen (2003)
Svenskøya, Svalbard	7760 ± 50	T-4167		Unpubl. data, Otto Salvigsen, reported by Harington (2008)
Kuröd, Bohuslän, Sweden	10.170 ± 125	Lu-1075		Berglund et al. (1992)
	10.360 ± 130	Lu-1074		
Finnøy, Norway	10.925 ± 110	T-4724		Blystad et al. (1983); Berglund et al. (1992).
Asdal, Denmark	11.240 ± 180	K-3741		Aaris-Sørensen & Petersen (1984); Berglund et al. (1992)
Östra Karup, Scania, Sweden	12.230 ± 130	Lu-1076		Berglund et al. (1992)
Kullaberg, Scania, Sweden	12.320 ± 125	Lu-602		Berglund et al. (1992)
	12.450 ± 145	Lu-660		
	12.480 ± 185	Lu-661		
Nordcemgrotta, Kjæpsvik, northern Norway	22			Lauritzen et al. (1996); Hufthammer (2001)
Hamnsundhelleren, western Norway	36–28		Middle Weichselian	Valen et al. (1996); Hufthammer (2001)
Nordcemgrotta, Kjæpsvik, northern Norway	39–42, >70 ± 8.5		Early Weichselian	Lauritzen et al. (1996); Hufthammer (2001)
Poolepynten, Prins Karls Forland, Svalbard, Norway	>45 (^{14}C) 150–80 (IRSL)	LuS-6155	Eemian to Early Weichselian (130–110)	This paper

(>4 years old) polar bears hunted in Svalbard in 1963–64, which are now held in the collection of the Natural History Museum, University of Oslo.

Identification and description of the polar bear mandible

The mandible was identified to be from a polar bear according to the following characteristics.

1. M_3 has two roots. In most brown bears the two roots have grown together (Erdbrink 1953).
2. The mandibular condyle lies on a line drawn along the alveoli of the tooth row. In brown bears the condyle is situated above this line (Nordmann & Degerbøl 1930).
3. The caudal margin of the coronoid process is strongly concave. In brown bears the margin is slightly concave (Stubbe 1993).

Overall, the mandible from Poolepynten is very well preserved. The only tooth preserved is the canine, whereas the incisors, premolars, and molars are absent. The dental alveoli where the teeth are missing have sharp and distinct edges. The canine is worn at the apex, and is assumed to belong to an adult specimen. The canine enamel is somewhat fractured. The muscle ridges and foramina are largely intact. The serrated surface of the mandibular symphysis is quite distinct, although it is a little worn at the edges. Overall, the mandible shows moderate signs of wear, which is consistent with some reworking before deposition. It has probably been introduced to the sediment either by slumping or ice rafting.

Measurements of the Poolepynten mandible are given in Table 2, together with measurements of the only two other known subfossil polar bear mandibles: one from Asdal, Denmark, as described by Nordmann & Degerbøl (1930), and one from Finnøy, Norway (measured by A.J. Nærøy, Archaeological Museum, Stavanger, Norway; Blystad et al. 1983). The Poolepynten mandible is smaller than the two other jaws in all dimensions except the

length and breadth of the M_3 alveoli, which are larger. The Asdal jaw was assumed to be from a male, whereas the Finnøy bear was certainly male, as the baculum was found with the nearly complete skeleton. These two males are not larger than present-day polar bears, according to data presented by Aaris-Sørensen & Petersen (1984) and in Table 3. The Poolepynten mandible has a total length and cheek tooth-row length of a male, whereas the mandible height is in the overlap zone between males and females (Figs. 4, 5). The size of the alveolus of the M_3 of the Poolepynten specimen falls in the range of the largest extant males (Fig. 6).

Larsen (1971) used the length of the cheek tooth-row to sex mandibles in extant individuals from Svalbard with high accuracy. All mandibles with a cheek tooth-row length of >70 mm were males. His measurement points were on the crowns of the teeth, whereas we have used the edges of the alveoli. However, these two measurements are not very different. Applying the cheek tooth-row length criterion of Larsen (1971) to sex the present jaw, it is classified as a male (Fig. 5). The determination of the ontogenetical age of the specimen by using the layering in the cementum of the canine has not been attempted. That method necessitates sectioning, and consequently the partial destruction of the find. However, by comparing the dimensions of the mandible with those of recent polar bears, as well as the level of wear of the canine, we assume that the jaw is from a fully grown specimen.

Discussion

A compilation of all of the finds of polar bear remains of pre-Holocene age (Table 1) shows that these finds are rare. This can perhaps be attributed to the fact that polar bears for the most part live and die on the pack ice, making their preservation in terrestrial sediments exceptional. The true age of the Poolepynten mandible is probably within the envelope of 80–150 Ky, as determined by the IRSL age determination for unit A. The lithostratigraphy of unit A suggests it was deposited during a period of high relative sea levels, subsequent to a regional deglaciation. The foraminifera content of unit-A sediments suggests advection of relatively warm, North Atlantic water to the site at the time of deposition. These conditions on the west coast of Svalbard were certainly met at the onset of the last interglacial period, the Eemian, some 130 Kya, and possibly at the onset of an early Weichselian interstadial, some 110 Kya (Mangerud et al. 1998). Our best age estimate for the Poolepynten mandible is thus 130–110 Ky.

Apart from the Poolepynten specimen, the two other reported finds of polar bear remains presumed to be from

Table 2 Measurements (mm) of the three known subfossil polar bear mandibles.

Measurement (mm)	Poolepynten, Svalbard	Asdal, Denmark	Finnøy, Norway
Mandible length	234.8	283	262
Mandible height	87.4	118	116
Cheek tooth-row length	75.2	79.9	76
Length of the M_3 alveoli	17.6	16	15
Breadth of the M_3 alveoli	11.0	10	11

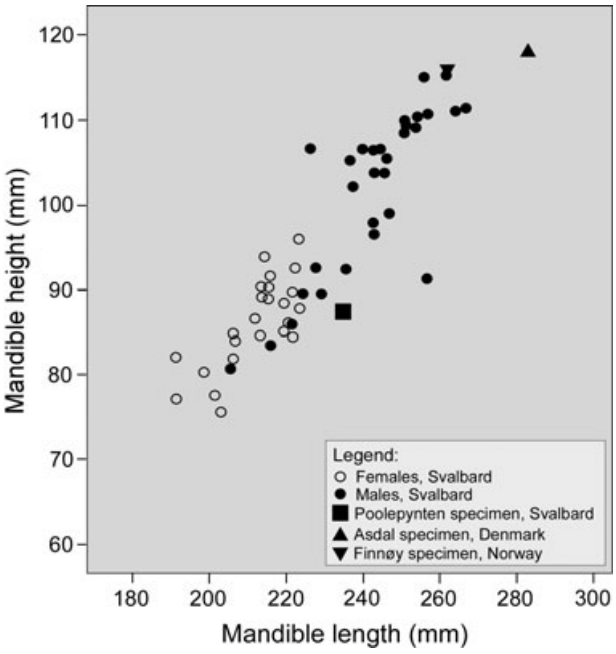

Fig. 4 The relationship between mandible length and mandible height in polar bears.

Table 3 Measurements (mm) of adult polar bear mandibles from Svalbard, 1963–64.

	Females				Males			
Measurement (mm)	*n*	Mean	SD	Range	*n*	Mean	SD	Range
Mandible length	25	210.57	11.85	175.8–223.5	30	242.53	14.57	205.4–266.8
Mandible height	25	85.49	6.24	68.7–96.0	30	101.87	9.66	80.7–115.3
Cheek tooth-row length	25	66.04	1.81	61.5–70.3	30	74.38	2.82	66.7–79.0
Length of the M_3 alveolus	25	14.03	1.01	11.4–16.1	29	16.34	1.22	12.8–18.5
Breadth of the M_3 alveolus	25	8.76	0.75	7.1–9.9	27	9.96	0.93	7.0–11.4

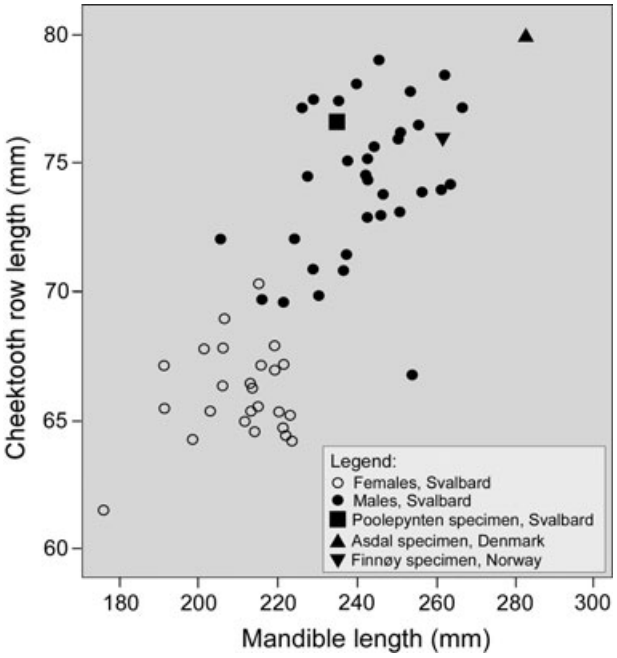

Fig. 5 The relationship between mandible length and cheek tooth-row length in polar bears.

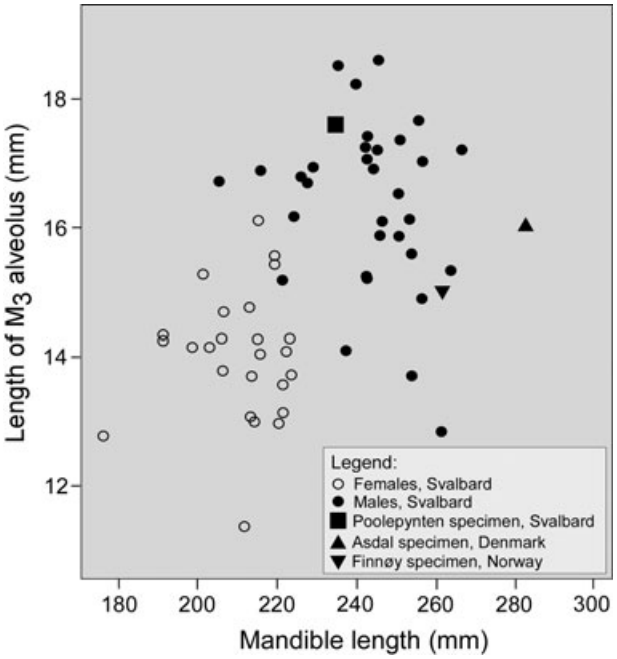

Fig. 6 The relationship between mandible length and length of the M_3 alveolus in polar bears.

Early Weichselian deposits are from Kew Bridge, London, and from cave sediments at Nordcemgrotta, in northern Norway (Table 1). The Kew Bridge specimen was dated on the basis of the stratigraphical position of the find: below it, stratigraphically, were sediments containing warm, interglacial forest fauna, thought to be of last interglacial (Eemian) age. There are no absolute age determinations for the fossil, but it has been assumed to be around 70-Ky old. The Kew Bridge find is special in that it is an ulna of a very large animal, considerably larger than present-day polar bears. Kurtén (1964) assigned it to a polar bear subspecies, *Ursus maritimus tyrannus*. The Kew Bridge specimen has recently been reinvestigated by scientists at London's Natural History Museum, and they are now confident that the Kew animal was a type of brown bear, *U. arctos* (Andy Currant, pers. comm. 2008). The finds from Nordcemgrotta were radiocarbon dated to 39–42 Ky B.P., and a $^{230}Th/^{234}U$ dating of calcareous concretions in the laminated sediments above the sedimentary horizon containing the fossil polar bear bones assigned them a minimum age of 70 ± 8.5 Ky B.P. (Lauritzen et al. 1996).

Opinions differ as to the timing of the polar bear branching off from the brown bear lineage. Kurtén (1964, 1968) suggested, on the basis of studies of the fossil material, a late origin of polar bears, and that perhaps the species had evolved as recently as 70–100 Kya. Some mitochondrial DNA (mtDNA) studies have confirmed Kurtén's supposition of a relatively late polar bear evolution from within the range of brown bear populations. However, age models based on molecular studies of evolutionary relationships among extant species of bears differ considerably as to the divergence time of polar bears from brown bears: Wayne et al. (1991) suggested that this happened 70–100 Kya; Talbot & Shields (1996) proposed that the process began some time in the interval 200–250 Kya, or perhaps a little earlier; whereas Yu et al. (2007) concluded that this might have occurred 930–1170 Kya. The age of the mandible from Poolepynten is close to the youngest estimates of the origin of the species, according to Kurtén (1968) and Wayne et al. (1991), and shows that the polar bear was a morphologically distinct species at that time.

Kurtén (1968) showed that the length of the lower molars fluctuated in size in Pleistocene and Holocene brown bears. There was an apparent increase from the Eemian interglacial through the Weichselian glacial stage, and thereafter a decrease during the Holocene up to the present day. The same postglacial reduction in size of brown bear molars was found by Østbye et al. (unpubl. ms.). A characteristic feature in the evolution of the polar bear is a reduction in the number and size of cheek teeth (Thenius 1953; Kurtén 1964; Vershchagin 1969). The reduction is particularly related to the size of M_2 and M_3. The size of the alveolus of the M_3 of the Poolepynten specimen falls within the range of the largest extant males (Fig. 6, Table 3). The other measurements also compare

well with extant males (Figs. 4, 5). The size of the two polar bear mandibles from Asdal and Finnøy are also comparable with extant males. Berglund et al. (1992) detected no size difference between Late Weichselian polar bears from southern Sweden and extant individuals. Consequently, the present subfossil polar bear material indicates little or no change in the size of polar bears during the Late Quaternary.

Summary and conclusions

The Poolepynten subfossil mandible, which we argue is from a fully grown male, is probably the oldest polar bear find discovered so far. Its age envelope is 150–80 Ky, but its true age is interpreted to be 130–110 Ky.

The Poolepynten mandible dimensions, combined with measurements of other fossil finds and extant males, suggests little or no changes in polar bear size during the Late Quaternary.

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