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by
POUL HENRICHSEN & HELEN GRUE

Med et dansk resumé:
Aldersbestemmelse af grønlandsk moskusokse
(Ovibos moschatus)

Резюме на русском языке
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МУСКУСНОГО ОВЦЕБЫКА
(Ovibos moschatus)

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Introduction

In 1974 the Danish Natural Science Research Council initiated a three year investigation of the Muskox *(Ovibos moschatus)* in Greenland in order to gain further knowledge about the biology of the species and the size of the population. A contributory reason for the project was the proposed North and East Greenland National Park, later a reality, which was to include most of the present Greenland Muskox range (Fig. 1).

The newest estimate of the population in North and East Greenland is 6,000-12,000 animals (VIBE 1971). Within the Park the Muskox is totally protected, but according to VIBE (pers. comm.) approximately 70 animals are shot annually outside the Park by Greenland hunters from Scoresbysund. During the period 1961-1967 27 Muskoxen were transferred from East to West Greenland; in 1978 this population was estimated to be approximately 200 animals (ROBY 1978).

As reliable age criteria are essential prerequisites for the understanding of many aspects of animal life (MORRIS 1972), special emphasis was placed on age determination in this project. Nowadays, the seasonal development of incremental lines in dental cementum provides the most accurate means of determining absolute age in mammals (for a review of the method see GRUE & JENSEN 1979). This and other methods of age determination should however be checked for accuracy against specimens of known age. When, as in diphyodont mammals, the sequential loss of deciduous teeth and/or the succession of permanent teeth takes place over an extended period, the stage attained can be a useful guide to the age of young animals. In the Muskox, the age of young animals can be determined even up to about 5 years by tooth succession as described by ALLEN (1913) and supplemented by TENER (1965), both authors mainly using material from North America.

The specific aim of the present study is to outline the validity and practical applicability of tooth succession and cementum incremental lines as age criteria in the Greenland Muskox. Stages of horn development are furthermore one of the most useful criteria for determining sex and age of the live Muskox and are also considered in this study.

The medical officer of health in Scoresbysund 1974-75, J. P. Brangstrup and his wife, were most helpful in collecting mate-

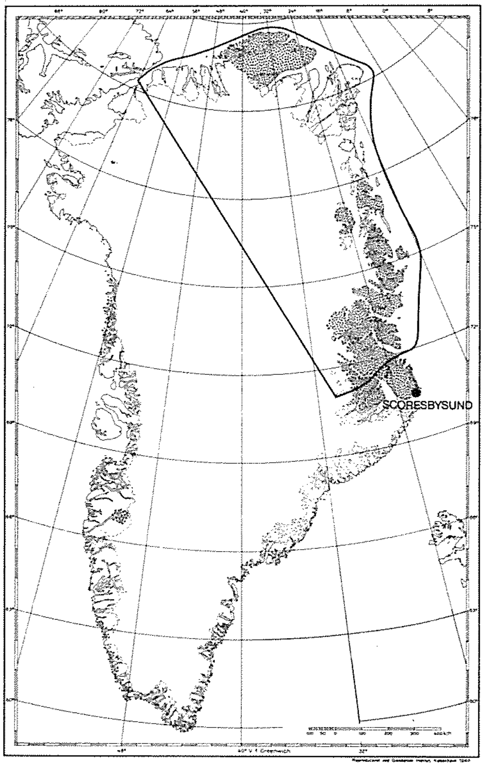


Fig. 1. Present distribution of the Muskox in Greenland and the border of the North and East Greenland National Park.

rial for the study. The collection of the Muskox skulls at the Zoological Museum, Copenhagen, was kindly made available by Dr. P. Valentin-Jensen and Dr. H. Baagøe. The study was supported by grants from the Danish Natural Science Research Council, nos. 511-5012 and 521/9-4.

Material

In the present study, 155 cleaned skulls with lower jaws of Muskox from Greenland belonging to the Zoological Museum, Copenhagen, were used. The material was collected between 1892-1975, the majority in Northeast Greenland, and a few in North and West Greenland. Five of the animals had spent part of or all their life in the Zoological Garden, Copenhagen.

Of the 155 skulls, 73 have unfinished and 82 have finished permanent tooth eruption. The date of death is known for 33 and 28 respectively and the majority of these were collected between March and September. To obtain specimens from the winter period 19 skulls were collected during the annual shooting at Scoresbysund in November 1974 - January 1975 by P. Henrichsen and H. Pedersen.

Methods

In the Muskox the permanent dental formula is $\frac{\text{I0 C0 P3 M3}}{\text{i3 c1 p3 m3}} \times 2 = 32$ (TENER 1965) and for the deciduous dentition $\frac{\text{dI0 dC0 dP3}}{\text{di3 dc1 dp3}} \times 2 = 18$, and these symbols will be used in the text and tables. For brevity when considered together, premolars and molars will be referred to as the buccal teeth.

Knowledge of the date of birth is necessary for accurate age determination. Information about the calving period has been reviewed by TENER (1965), who states that in Canada and Greenland calving takes place from late April to the end of May, in Canada possibly extending to mid June. VIBE (1971) mentions that calving in Greenland takes place in May-June and MILLER et al. (1977) found that a few calves are born before the first week of April in the Arctic Archipelago. On the Danish Polar Bear Expeditions in 1973 and 1974 the first calves were seen both years on May 1 (P. HENRICHSEN, unpubl.)

From this the calving period appears to last from April, possibly even late March, to early June. In calculating the age, it was decided to regard all animals as being born on May 1.

TOOTH ERUPTION AND ATTRITION

The skulls of the 33 animals with unfinished permanent tooth eruption and known date of death were arranged in three different ways for comparison, viz.;

1. According to size of skulls, closing of sutures and tooth succession and wear. The age is calculated from the assumed date of birth and the date of death and is later referred to as the calculated age (p. 5).

2. According to eruption of incisors and the maxillary teeth as described by TENER (1965).
3. According to eruption of both mandibular and maxillary teeth.

A description of tooth succession based on the skull material was prepared. As a complete ontogenetic series illustrating the sequential loss of deciduous teeth and/or the succession of permanent teeth could not be obtained based on the 33 skulls of known age, the 40 skulls of unknown age were used as a supplement where required. As the tooth crown attains a dark stain shortly after it appears above the gum, all parts of the tooth visible in the live Muskox are readily discernible in cleaned skulls. In studies of tooth succession in general, a varying terminology has been used to describe stage of eruption, but in the present study the terms outlined below will be used:

Unerupted tooth: entirely below (Ea) or with parts of the crown above (Eg) the alveolar border, but never stained.

Erupting tooth: parts of the crown stained (E).

Erupted tooth: both the deciduous tooth (d) and the permanent (P) have a continuous stain around the crown.

HORN DEVELOPMENT

Based on the ontogenetic series, animals typical for the specific age groups have been selected and drawings of their horns are given.

CEMENTUM INCREMENTAL LINES

For counting cementum incremental lines the first permanent incisor was used. Teeth were decalcified in 5% nitric acid (HNO_3) using 0.1 ml per mg tooth. When the fluid was shaken constantly decalcification required 30-36 hours. 12-16 μ thick sagittal sections were prepared by means of freeze sectioning. Sections were stained and mounted as described by GRUE & JENSEN (1979).

Results and discussion

TOOTH ERUPTION AND ATTRITION

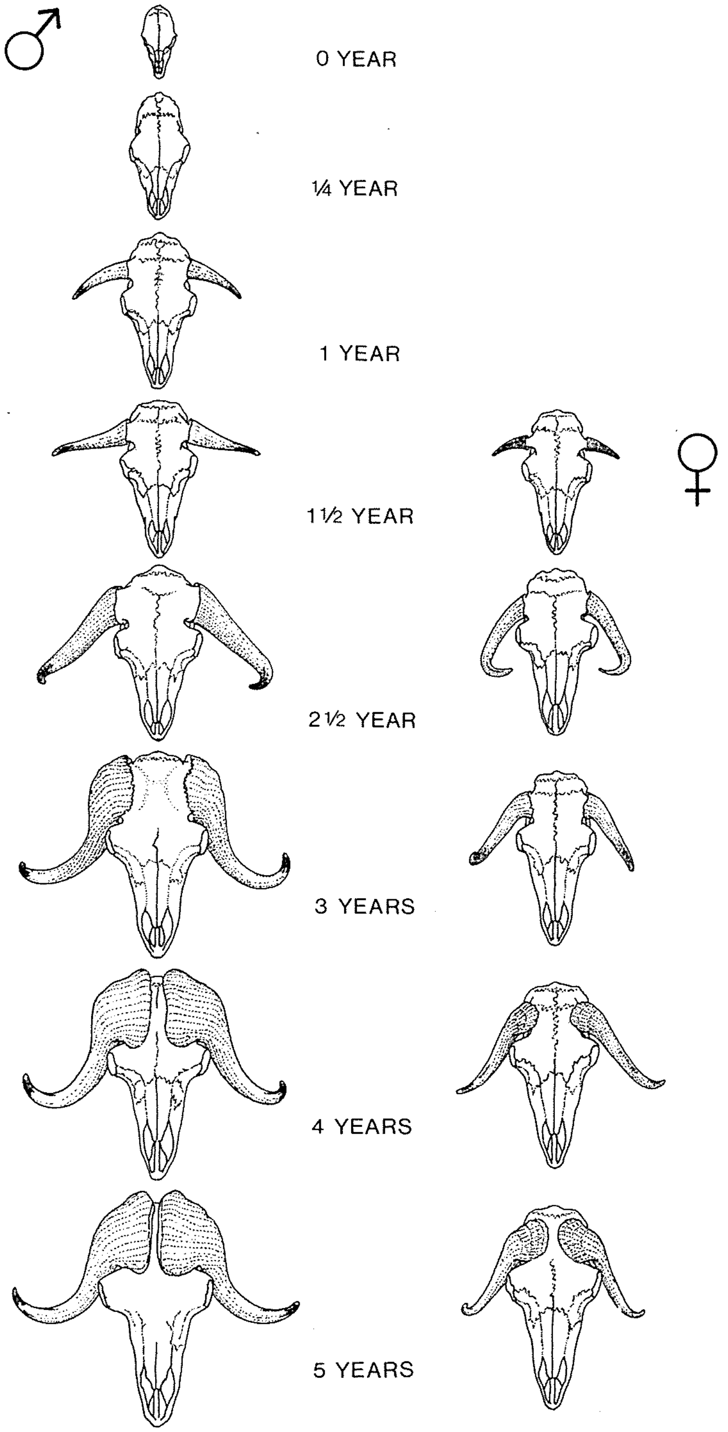
The chronological arrangement of the 33 animals with known date of death and their calculated age is given in Table 1. By tooth succession, no. 3443 and no. 3773 were judged to be younger than no. 650 and no. 1416 respectively, but older by tooth wear. In both, tooth succession was considered delayed and they were arranged according to the calculated age (no. 3443 died from *Meteorhismus ruminis* in the Copenhagen Zoo after having been caught in Greenland the same year (ANDERSEN 1966).

ALLEN (1913) described eruption and attrition of the teeth twice in the same article, but with considerable lack of agreement. These descriptions were however both based on the same material. Based on an unknown number of animals TENER (1965) judged the descriptions given by

Ref. no.	Sex	Date of death	Calculated age Months	Age determined by tooth succession: Tener (1965) Years	Age determined by tooth succession: This study Years	Incremental lines: No. of lines	Incremental lines: Age (assessed from no. of lines) Years	Incremental lines: Age (assessed from no. of lines) months
ph-1	–	–	0-2 days	0	0	–	–	–
3681	♀	–	20 days	0	0	–	–	–
1747	♂	15-06-1932	1	0	0	–	–	–
650	♂	12-08-1892	3	0	0	d0	0	3
3381	♂	16-09-1961	4	0	0	–	–	–
3443	♂	14-09-1964	4	0	0	–	–	–
1744	♀	01-09-1932	4	0	0	d0	0	4
3444	♂	19-11-1964	6	½	½	–	–	–
ph-2	♂	18-03-1933	10	1	½	d1	0	10
1609	♂	21-06-1933	13	1	1	d1	1	1
3002	♀	16-08-1956	15	1	1	d1	1	3
1386	–	05-09-1925	16	1	1	d1	1	4
1387	–	05-09-1925	16	1	1	d1	1	4
1748	♂	07-09-1931	16	1	1	d1	1	4
3761	♂	18-01-1975	20	1½	1½	d2	1	8
3763	♂	18-01-1975	20	1½	1½	d2	1	8
3774	♀	18-01-1975	20	1½	1½	d2	1	8
3775	♀	18-01-1975	20	1½	1½	d2	1	8
ph-3	♂	18-03-1933	22	2	1½	d2	1	10
1416	♀	May-Aug. 1930	24-27	2	2	1	2	0-3
3773	♀	18-01-1975	32	2	2	2	2	8
ph-4	♂	18-03-1933	34	2½	2½	2	2	10
2409	♂	25-07-1947	38	3	3	2	3	2
2410	♂	25-07-1947	38	3	3	2	3	2
771	♀	25-07-1900	38	3	3	2	3	2
3768	♀	18-01-1975	44	3	3	3	3	8
3776	♀	18-01-1975	44	3	3	3	3	8
ph-5	♀	18-03-1933	46	3	3	3	3	10
651	♀	12-08-1892	51	4	4	–	–	–
778	♀	Aug. 1900	51	4	4	3	4	3
2424	♂	30-08-1947	51	4	4	3	4	3
3765	♂	Nov. 1974	54	4	4	5	5	6
3767	♂	04-12-1974	55	5	4½	5	5	7

Table 1. Skulls of 33 Muskox with unfinished permanent tooth eruption and known date of death, arranged chronologically according to size of skull, closing of sutures, tooth wear, etc. The classification is compared to age assessed by means of tooth succession, cementum incremental lines and horn development (p. 7).

d: deciduous tooth.


♂
0 YEAR
¼ YEAR
1 YEAR
1½ YEAR
♀
2½ YEAR
3 YEARS
4 YEARS
5 YEARS

ALLEN to be "essentially correct except for a number of errors in timing of tooth eruption". TENER presents a résumé of ALLEN'S first description - of the incisiform and the maxillary teeth only - with his own corrections but without specifying where the errors occur.

Using the description given by TENER (1965) agreement was found in all but three cases of the animals in Table 1.

This was the "best fit" that could be achieved after defining terms such as "fully grown and erupted", "almost fully grown", and deciding which kind of tooth was to be used in the various age classes.

In spite of the close agreement the need was felt for a more detailed description of succession of the maxillary teeth. Furthermore, it was decided to include also the mandibular buccal teeth, as lower jaws are much easier to collect than the rest of the skull. The morphology of the tooth crown of the Muskox has been described by LOOMIS (1925), but as the terminology was found difficult to use, terms from the trituburcular theory as presented by SPINAGE (1973) are used in the present study (Fig. 2). The abbreviations used are slightly different from those of SPINAGE, the latter being established ones but difficult to understand. The description of tooth eruption and attrition outlined in the present study and the one given by TENER (1965) are presented in Table 2.

In three cases disagreement between the two descriptions occurs; this concerns the dentition at birth (0 year), at 3 and at 5 years. Based on a calf less than two days old from the Copenhagen Zoological Garden and verified on a calf with very slightly worn hoofs found dead in Northeast Greenland in 1978, only the three incisors were found to be erupted at birth. All other teeth had parts of the crown under the gum and were erupting, whereas TENER considered all deciduous teeth to be erupted at the time of birth. In the 3-year age class there was disagreement about the deciduous premolars, where TENER uses presence of dP4 surmounting P4 as a criterion. In this study however individual variation in the time of loosing the premolars was found, and this criterion is considered unsuitable for age determination. In the 5-year age class the most important criterion in the description by TENER is the functional canine. In this study animals determined by incremental lines to be more than 5 years old and collected in the area between 74° and 78°N often had one or both canines missing and/or unerupted (Plate 1, B). According to TENER the age of these animals would be underestimated.

Lack of canines in the Muskox in Greenland is an anomaly which is believed to be genetically determined (HENRICHSEN 1980). Both missing and unerupted canines were rarely found south of 72°N, but in the northern part of the range 20 animals out of 32 (62.5%) and in the southern 3 out of 30 (10%) had one or both canines missing or unerupted. This shows that the

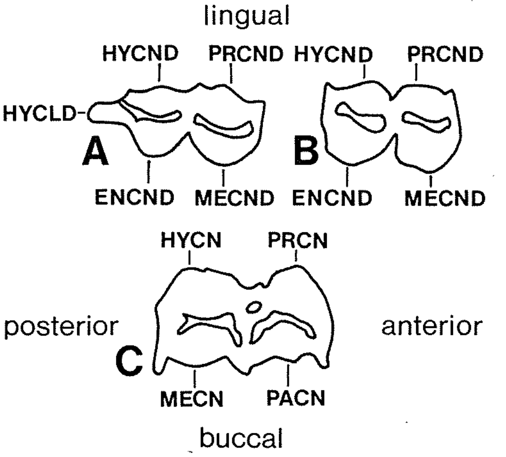


Fig. 2. Tooth crown nomenclature of permanent mandibular and maxillary molars. A = m3. B = m1-2. C = M1-3. ENCND = entoconide. HYCLD = hypoconolide. HYCN = hypocone. HYCND = hypoconide. MECN = metacone. MECND = metaconide. PACN = paracone. PRCN = protocone. PRCND = paraconide.

Age in years	TENER (1965)	This study
0	Born with di1-3, dc and dP2-4 erupted and with M1 concealed in the alveolus.	Born with dp2 and dc unerupted, dp3-4 and dP2-4 erupting and di1-3 erupted. M/m1 are found as loose parts in the alveolus.
½	The anterior half of M1 projects above the alveolus, the posterior half being about even with it. dP2-4 show considerable wear.	dc and dP/dp2-4 are erupted and worn on all structures except the posterior parts of dP4's HY- and MECN. m1 is erupting with PR- and MECND above and EN- and HYCND below the gum. M1 is erupting with PACN above the gum, PR- and possibly MECN above the alveolar border. The erupted parts of M/m1 are unworn.
1	dP2-4 are much worn and M1 is fully grown and functional. The anterior half of M2 projects slightly above the alveolus, the posterior half being above level with the alveolar border. dP2-4 are still present.	All structures on dP4 are worn. m1 is erupted and worn on all structures. M1 is erupting and without wear on the posterior parts of HY- and MECN. m2 has PRCND just above or below the gum, while ME- and HYCND are above and ENCND below the alveolar border. M2 has PACN above and the other cones below the alveolar border.
1½	dP2-4 are further worn, M1 is grown and functional, the anterior half of M2 is above the alveolus and the posterior half levels with the edge. di1-3 and dc are still present.	m2 has PR- and MECND above the gum and is worn on PRCND. M1 is erupted and worn on all structures. M2 has PACN almost above the gum and PRCN above the alveolar border.
2	dP2-4 are much worn, the crown pattern on dP2-3 being obliterated. M1 is worn, the anterior half of M2 is unworn though fully emerged. M3 is still fully enclosed in the alveolus. The tip of i1 appears just above the alveolar border.	m2 is erupting and worn on all conides except the posterior parts of HY- and ENCND. M2 is erupting with PA- and PRCN above and ME- and HYCN below the gum and it is worn on PACN. i1 and M/m3 are in the alveolus.
2½	dP2-4 are worn nearly to the roots. M1 is worn considerably. M2 is functional and worn on the anterior half and slightly on the posterior half. M3 is still encapsulated. i1 is fully grown and i2 is still enclosed. di2-3 and dc are not yet shed.	m2 is erupted and worn on all structures. M2 is erupting and worn except on the posterior parts of HY- and MECN. m3 has PRCND above or just below the gum. i1 is erupted and i2 is in the alveolus.
3	dP2-3 have been shed but dP4 still surmounts P4. P2-3 are about half their mature height and P4 is above the alveolus. M1 is worn further, M2 shows some wear and M3 is appearing above the alveolus.	M2 is erupted and worn on all structures. m3 has PR- and MECND above the gum; the conides are not worn on the posterior parts. M3 has PR- and possibly also PACN above the gum and HY- and MECN above the alveolar border. P/p2 are erupting and unworn. dP/dp3 may still be found above P/p3, which - especially if dP/dp3 are lost - are erupting. dP/dp4 surmount P/p4. i2 is erupted and i3 is in the alveolus.
4	P2-4 and M3 are almost fully grown but show little wear. i1-3 are fully grown but dc still surmounts the growing c.	m3 has all structures except HYCLD above the gum, the posterior parts of HY- and ENCND are worn. M3 is worn on PA- and possibly also on PRCN. P/p 2-4 are erupted and also i3.
5	At 5 years of age c has become functional, all other teeth show wear to varying degrees.	At 4½ years of age M/m3 are erupted and worn on all structures. Considerable variation is found concerning the eruption of c (see p. 8).

Table 2. Description of tooth eruption and attrition based on 73 Muskox from Greenland compared with the description given by TENER (1965). For explanation of crown nomenclature see Fig. 2.

Age in years	Incisiform teeth i1	i2	i3	c	Premolars p2	p3	p4	P2	P3	P4	Molars m1	m2	m3	M1	M2	M3
0	d	d	d	dEg	dEg	dE	dE	dE	dE	dE	Ea	–	–	Ea	–	–
½	d	d	d	d	d	d	d	d	d	d	E	–	–	E	–	–
1	d	d	d	d	d	d	d	d	d	d	P	Eg/E	–	E	Eg	–
1½	d	d	d	d	d	d	d	d	d	d	P	E	–	P	E	–
2	d/Ea	d	d	d	d	d	d	d	d	d	P	E	Ea	P	E	Ea
2½	P	d/Ea	d	d	d	d	d	d	d	d	P	P	E	P	E	Ea
3	P	P	d/Ea	d	E	d/E	d/E	E	d/E	d/E	P	P	E	P	P	E
4	P	P	P	d/Ea	P	P	P	P	P	P	P	P	E	P	P	E
4½	P	P	P	P^x	P	P	P	P	P	P	P	P	P	P	P	P

Table 3. Eruption pattern of mandibular and maxillary teeth in the Muskox. For explanation of abbreviations, see p. 5. P^x = canine may be missing or remain unerupted.

state of eruption of the canines should be used with the greatest care in age determination, and that reference always should be made to the buccal teeth.

The last of the buccal teeth to erupt are the third mandibular and maxillary molars (m3 and M3) and this is judged to happen when the animals are approximately 4½ years old. The number of incremental lines in the first incisor of animals in this group, however, indicates that animals older than 4½ years have been included (Table 1). Thus age determination based on tooth succession in the Muskox in Greenland is considered reliable up to the age of 4 years.

The eruption pattern of the maxillary and mandibular teeth in the Muskox is summarized in Table 3. In determining the age of individuals with unerupted permanent dentition, it is recommended first to consult Table 3 and then check the results using the verbal description in Table 2, and to use the eruption pattern of molars followed by incisors.

HORN DEVELOPMENT

Sex and age determination of the live Muskox in the field has been attempted by a number of authors using not only horn development but also body size, length of guard hair, urinating posture etc. (GRAY 1973, ALENDAL 1974, HUBERT 1974).

Drawings of the horns according to sex and age are shown in Table 1. For all specimens used, age has been determined from tooth succession and/or incremental lines and all had been collected in the same area. Because of broken horns on many of the younger animals and lack of material some of the drawings are based on few specimens and some categories are not represented at all. Due to the relatively small size of the horns it was found difficult to determine sex and age by the horns alone in animals less than two years old. In males from two to four years old, age determination based on the horns was reasonably reliable. In older age classes only slight changes with age occurred, changes that are difficult to see on live animals. As a supplement to the descriptions of horn development given by ALLEN (1913) and TENER (1965) the drawings may however help field workers to gain experience more easily in sex and age determination of the Muskox.

CEMENTUM INCREMENTAL LINES

The first permanent incisor of 69 Muskox were investigated. All teeth showed a distinct layer of cementum, thin along the sides of the root, but in mature teeth with pads of cementum round the root apex (Plate 1, A and C). Counting of lines was most easily performed at the apical region of the root, where distance between neighbouring lines was at its largest. In the Muskox, as in many other ungulate species, the root apex of incisors is frequently exposed to resorption which may cause disturbance of the pattern of incremental lines. Therefore it was often necessary also to count the lines in the thin cementum layer at the cervical region of the root.

In teeth where the pulp cavity ramifies, the cementum structures are often indistinct. Such teeth are readily recognized, as foramen apicale are usually situated on the side of the root (Plate 1 A).

It has generally been accepted that for correct determination of age based on cementum incremental lines, age at tooth eruption must be taken into consideration. This is however only correct for species where cementum formation is initiated shortly before or just at the time of eruption. In at least some ungulate species initiation of cementum formation and time of eruption do not coincide, and both cementum and incremental lines may appear before the tooth erupts. (for reference see GRUE & JENSEN 1979).

In order to assess when cementum apposition starts in the Muskox, unerupted permanent first incisors were sectioned. Judging from the stage of succession it was established that apposition is initiated already in the second summer before the animal is 15 months old, that means more than a year before the tooth erupts (Table 3).

To establish when the first incremental line is formed both unerupted permanent first incisors were furthermore sectioned in two animals judged by tooth succession to be two years old. No. 1416 was shot between May and August and thus 24-27 months old, while the date of death of no. 2421 is not known. One incremental line is found in each of the first incisors in both individuals (Plate 2 A), and apparently in the Muskox the first line becomes visible in the animal's second year of life. As root development is still in progress at this age, the first line can easily be distinguished from succeeding ones, as it does not continue round the root apex.

For a correct classification in age groups knowledge of season for development of incremental lines is required. For this purpose 30 Muskox judged from their tooth succession to be more than 15 months old were used. Fig. 3 shows for each month the number of animals with a developing incremental line bordering the periodontal membrane, as a percentage of the total number of animals available for the parti-

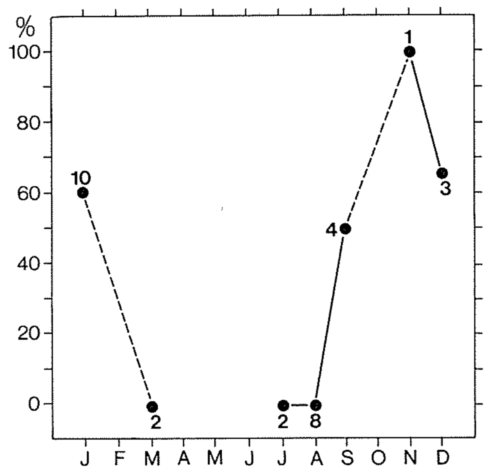


Fig. 3. Development of incremental lines in teeth of the Muskox in relation to time. For each month the number of specimens showing a developing incremental line is plotted as a percentage of the total number available for that month. (N = 30).

Plate 1.

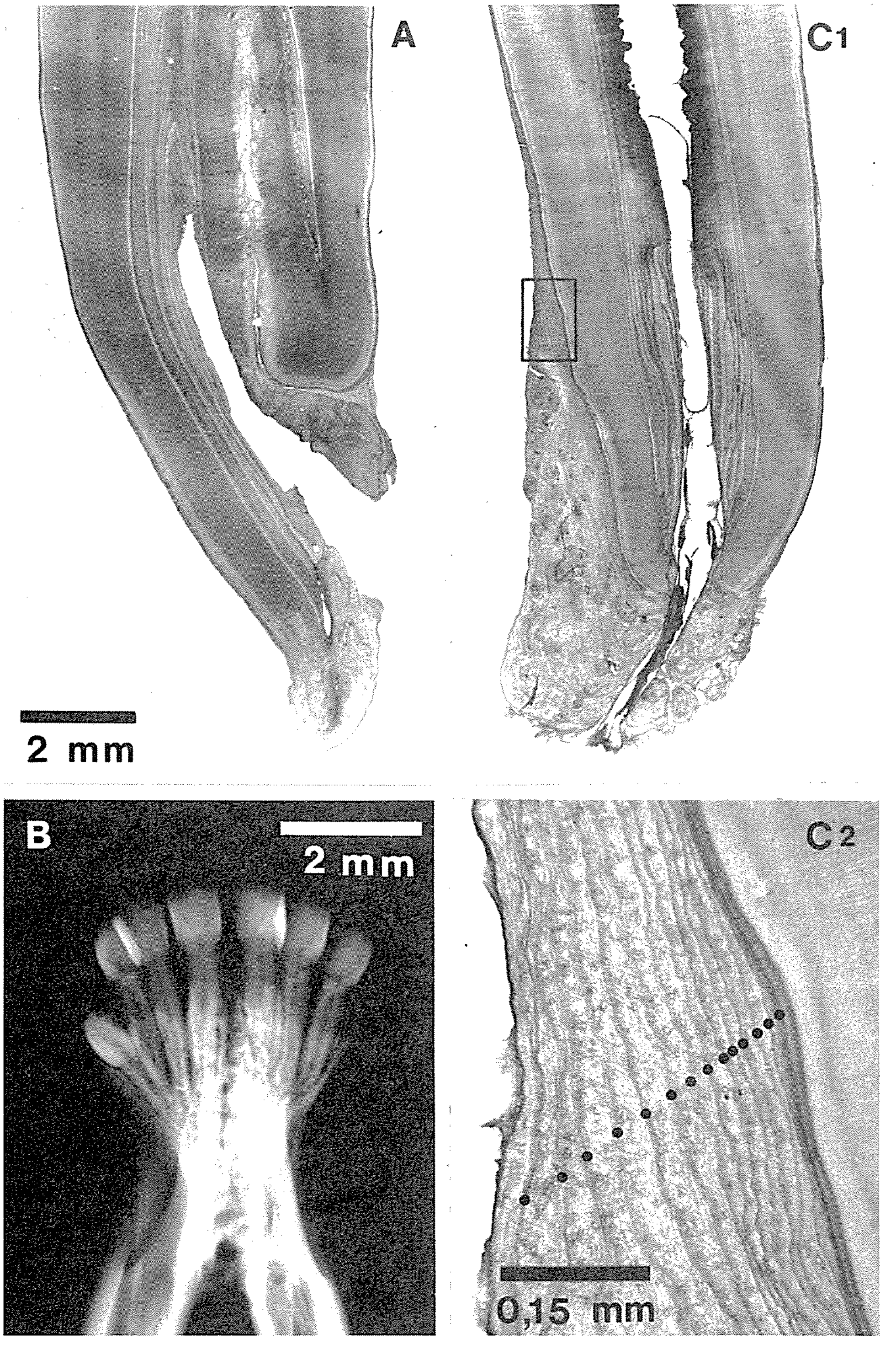
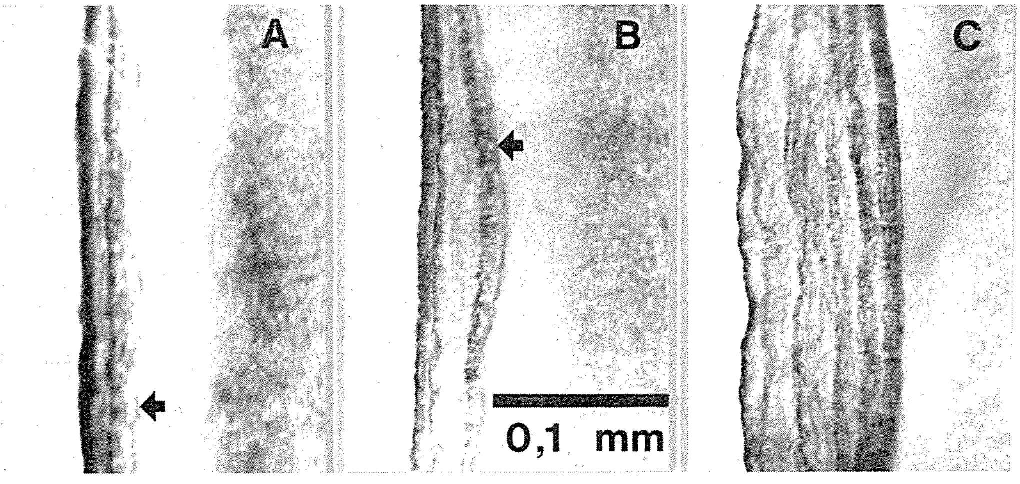


Plate 2.



Plates: Sections of teeth of Muskox from Northeast Greenland.

Plate 1.

A. No. 3765 ♂. Shot November 1974. First permanent incisor. Abnormal pulp cavity with several ramifications. Foramen apicale approximately 3 mm above tip of the root.

B. No. 2246 ♀. Shot summer 1938. Canine anomaly. X-ray of mandible viewed from the ventral side. Left canine not formed, right canine formed, but not erupted. Judged by number of incremental lines to be 6 years old.

C. No. 1384 ♀. Shot September 1925. First permanent incisor. 14 incremental lines.

Plate 2.

A. No. 1416 ♀. Shot May-August 1930. First permanent incisor. One incremental line.

B. No. 3773 ♀. Shot January 1975. First permanent incisor. Two incremental lines.

C. No. 990 ♂. Collected between 74° and 78°N. Unerupted canine with five incremental lines.

cular month (cf. GRUE & JENSEN 1979). Individuals from July and August have lightly stained cementum as the outermost layer. Deposition of incremental lines is observed in animals killed between September and January. However, lack of material from February prevents an accurate assessment of time when development of the line ceases. Fig. 4 illustrates the chronological sequence of incremental line formation and eruption of the first permanent incisor (cf. GRUE & JENSEN 1979). In no. 3773 the eruption of permanent teeth is considered delayed and the animal is arranged in Table 1 in agreement with the calculated age (p. 5). Based on the cementum structures this proves to be correct, as two incremental lines are visible (Plate 2 B).

As incremental lines in unerupted and erupting incisors of the Muskox were present, cementum structures in the unerupted canines in sub-adult and adult individuals were examined (cf. also GRUE & JENSEN 1979). One canine from four animals with one or both canines hidden in the jaw was sectioned. Each tooth had a well-developed cementum layer with close-lying incremental lines. Also the number of lines present corresponded to the number found in i_1 of the same animal. However, the character of the lines in these cani-

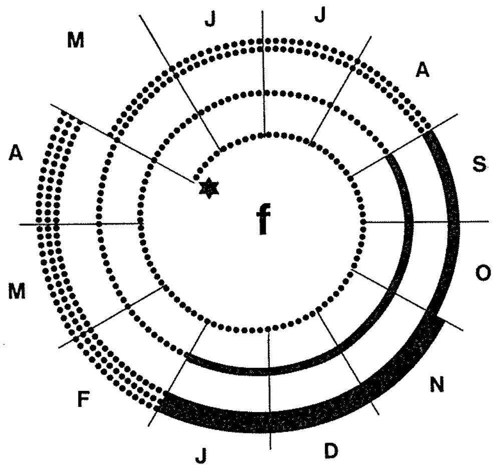


Fig. 4. Development of incremental lines in relation to tooth replacement in permanent first incisor in the Muskox.

Asterisk = time of birth, dots = period for development of light-staining cementum, solid bars = period for development of incremental line in the permanent tooth. The single row of dots indicates permanent tooth not yet visible above the gum. Double row of dots and narrow bar indicate erupting permanent incisor, and three rows of dots and broad bars indicate erupted permanent incisor.

nes generally made counting more difficult than in the corresponding incisor (Plate 2 C).

In the Muskox the process of tooth succession lasts over four years (Table 3). Based on the hypothesis that in deciduous teeth, cementum incremental lines also appear on an annual basis, two lines should be expected in the deciduous first incisor in the Muskox, and three in the last premolar, at the time the teeth are shed. The deciduous first incisor of 13 animals listed in Table 1 have been sectioned. It is seen that in each case the expected number of lines was found. The last deciduous premolar, found on top of the protruding permanent tooth at the age of approximately 36 months (Table 3) from three animals was also sectioned, and in each three incremental lines were observed.

Based on these findings it seems reasonable to conclude that in the Greenland Muskox cementum incremental lines are formed according to a seasonal cycle in both deciduous and permanent teeth. One line is formed each year, but the first line in the permanent incisor occurs however in the second year of life, when the animal is between 16 and 21 months old.

This was further supported by a Muskox of known age. An adult bull which in 1961 as a calf had been transferred from Northeast to West Greenland was illegally shot in August 1970. The bull was then 9 years and 3 months old and had 8 incremental lines, the 9th probably would start forming in the beginning of September.

General knowledge of the season during which incremental lines are formed enables correct grouping in age classes, usually also for individuals with unknown date of death (GRUE & JENSEN 1979). When the date of death falls outside the normal period for line development, relative thickness of the outermost cementum layer should indicate how long the animal lived after completion of the last formed incremental line. In the Muskox such an estimate is however very unreliable and in most cases impossible, because the annual layers are very thin.

Table 4 shows age composition based on the number of incremental lines in 69 Muskox including the 19 animals collected during the hunting season from November 1974 to January 1975.

Only little information exists regarding the maximum age of the Muskox. BUCKLEY et al. (1954) suggest a potential longevity of at least 25 years based on a female captured as a calf in Greenland in 1930 and released on Nunivak Island off the West coast of Alaska in 1936. The animal died in 1953, and grinding surfaces of the teeth were reported to be in fairly good condition.

No. of incremental lines	No. of Muskox ♂	No. of Muskox ♀	Total
1	1	1	2
2	5	3	8
3	2	7	9
4	1	4	5
5	7	4	11
6	5	1	6
7	2	8	10
8	3	2	5
9	0	1	1
10	3	4	7
11	2	0	2
12	1	0	1
13	0	1	1
14	0	1	1
	32	37	69

Table 4. Number of incremental lines in the permanent first incisor in the Muskox from Greenland used in the present study.

The highest number of incremental lines found in the material collected during the winter 1974-75 was in a female shot in January. Based on the designated birth, May 1, the 14 lines observed indicate the age of 14 years and 8 months (Plate 1 C). In the material from the Zoological Museum the highest number of lines found was 13; as the animal was shot in September the age is assessed to 14 years and 4 months. Grinding surfaces at this age were found much worn and a maximum age of approximately 20 years seems likely for the Muskox in Greenland.

Conclusions

In the present study three criteria applicable for determining age of the Muskox have been investigated, cementum incremental lines, tooth succession and horn development.

It was found that in the Greenland Muskox seasonal development of the root cementum allows exact determination of age based on the number of incremental lines when season of death of the animal is known. The first line appears in the second year of life at the age of 16-21 months, and the normal period for line development is September-January.

When the season of death is unknown, age can only be assessed as N or N+1 where N indicates the number of incremental lines, because an estimate of the length of the period the animal lived after completion of the last formed lines is very unreliable in this species.

Cementum incremental lines provide the only possible means of establishing exact age, and is a most reliable one, after completion of permanent tooth eruption. However, the method has the disadvantage that it requires dead material.

Tooth succession is found reliable for age determination up to four years when applied to cleaned skulls, and it is recommended to use the eruption pattern of molars followed by incisors. It is concluded that because of lack of canines in animals from certain areas in Greenland the eruption pattern of canines cannot be considered a reliable criterion.

For live, immobilized animals age determination by means of tooth succession can be based on incisors only, as inspection of the buccal teeth in live animals is most difficult; thus in this situation the method is applicable only up to the age of approximately three years (Table 3).

Stage of horn development is found reasonably safe for establishing age in both sexes from two to four years, in males possibly extending to four and a half. Although in younger animals the small size of the horns makes classification difficult, this method provides a most useful means of assessing the age of live animals in the field.

Dansk resumé

Aldersbestemmelse af grønlandsk moskusokse *(Ovibos moschatus).*

Tre metoder til aldersbestemmelse af den grønlandske moskusokse er blevet undersøgt. De omfatter tand- og hornudvikling samt vækstlinier i rodcementen på første fortand. Undersøgelserne er foretaget på et materiale tilhørende Zoologisk Museum, København, og omfatter 155 kranier indsamlet i perioden 1892-1975 fortrinsvis i Nordøstgrønland, suppleret med 19 stk. fra Scoresbysund nedlagt i jagtsæsonen 1974-75.

Af de undersøgte individer med kendt dødsdato var 33 i gang med tandskifte. Ud fra disse er frembrudsmønsteret for mælketænder og blivende tandsæt beskrevet (Tabel 2 og 3). Til beskrivelse af tandkronens struktur er benyttet nomenklatur fra den trituberculate teori (Fig. 2). Ud fra tandskiftet kan alderen af den grønlandske moskusokse bestemmes indtil dyret er 4 år. Ved denne alder er det blivende tandsæt i funktion bortset fra underkæbens fortandslignende hjørnetand og over- og underkæbens bageste kindtand, som er i frembrud (Tabel 3). En yderligere aldersklassificering baseret på de nævnte tænder vil være forbundet med stor usikkerhed, hvilket for hjørnetandens vedkommende skyldes, at den hos dyr fra visse områder hyppigt er rudimentær eller endog helt mangler (Tavle 1C). Med hensyn til de bageste kindtænder viser antallet af vækstlinier i den tilsvarende første fortand, at frembruddet kan strække sig over så lang tid, at der er risiko for, at flere aldersgrupper slås sammen (Tabel 1).

Til studiet af vækstlinier er benyttet histologiske præparater af den første fortand fra 69 moskusokser, hvoraf én var af kendt alder (9 år 3 mdr.).

Den grønlandske moskusokse viser en klar årscyklus i dannelse af rodcement i såvel mælketand som blivende tand, og det må antages, at liniernes antal svarer til dyrets alder i år (Tabel 1). Den blivende, første fortand er brudt frem og i funktion, når dyret er ca. 2½ år, men undersøgelser af ikke frembrudte tænder viser, at cementdannelsen starter ca. 1 år inden tanden bryder frem, og første linie dannes, når dyret er 16-21 mdr. (Fig. 4). Disse iagttagelser støttes af dyret med kendt alder, som havde dannet 8 vækstlinier. På grundlag af dyr med kendt dødsdato kunne perioden for liniedannelsen bestemmes til september-januar (Fig. 3). En eksakt aldersangivelse kan kun gives, såfremt årstiden for moskusoksens død er kendt. Som følge af det totale cementlags ringe tykkelse er det ikke muligt at vurdere, hvor lang tid et givet dyr har levet efter dannelsen af den yderste vækstlinie, og når dødsdato ikke kendes, kan alderen derfor kun fastsættes som »N eller N+1«, hvor N er antallet af vækstlinier. Det ældste dyr i materialet var en hun (skudt i januar), hvis alder bestemtes til 14 år og 8 mdr.

Den praktiske anvendelse af de to metoder begrænses af, at dødt materiale skal være til rådighed. Ved undersøgelse af fortændernes frembrudsmønster på levende, bedøvede individer vil det dog være muligt at aldersbestemme dyrene indtil en alder af ca. 3 år (Tabel 3).

Tegninger af hornudviklingen for de opstillede aldersgrupper er udarbejdet (Tabel 1) og kan benyttes ved køns- og aldersbestemmelse af moskusokser under feltarbejde. Hornudviklingen alene kan med rimelig sikkerhed dog kun benyttes i alderen 2-4 år, for hannerne måske til 4½ år.

Резюме на русском языке

ОПРЕДЕЛЕНИЕ ВОЗРАСТА ГРЕНЛАНДСКОГО МУСКУСНОГО ОВЦЕБЫКА *(Ovibos moschatus)*

Были исследованы три способа определения возраста гренландского мускусного овцебыка. Они основаны на развитии зубов и рогов, а также на ростовых линиях в корневом цементе первого зуба-резца. Исследования проведены на материале, принадлежащем Зоологическому Музею в г. Копенгагене, и охватывают 155 черепов, собранных в периоде с 1892 по 1975 г., главным образом в Северовосточной Гренландии, дополненых 19 черепами из Скоресбизунда от особей, убитых в течение сезона охоты 1974-1975 г.

Из обследованных особей, дата смерти которых известна, у 33-х происходила смена зубов. На основании этих особей описана характеристика прорезывания молочных и постоянных комплектов зубов (табл. 2 и 3). При описании структуры зубного венца применяется терминология из тритуберкулятной теории (фиг. 2). По смене зубов возраст гренландского мускусного овцебыка можно определить, пока животное не старше 4 лет. В этом возрасте вступил в действие постоянный комплект зубов, за исключением похожего на резец клыка нижней челюсти и задних коренных зубов верхней и нижней челюстей, находящихся на стадии прорезывания (табл. 3). Дальнейшая классификация по возрасту на основании вышеупомянутых зубов будет страдать значительной ненадежностью, что в случае клыка объясняется тем, что он у животных из некоторых местностей часто остается рудиментарным или даже совершенно отсутствует (табл. 1 C). Что касается задних коренных зубов, число ростовых линий в соответствующем первом резце указывает на то, что период прорезывания может быть настолько длительным, что состоит риск смешивания нескольких возрастных групп (табл. 1).

Для изучения ростовых линий использовались гистологические препараты первого резца 69 мускусных овцебыков, из которых один был известного возраста (9 лет и 3 месяца). Гренландский мускусный овцебык выказывает четкий годовой цикл образования корневого цемента как в молочных, так и в постоянных зубах, и допустимо предполагать, что число линий соответствует числу годов возраста животного (табл. 1). Постоянный первый резец прорезался и вступил в действие, когда животному прибл. 2 ½ года, но исследования непрорезавшихся зубов показали, что образование цемента начинается на прибл. 1 год раньше прорезывания зуба, и что первая линия образуется в возрасте от 16 до 21 месяцев (фиг. 4). Эти наблюдения подтверждаются животным известного возраста, у которого было образовано 8 ростовых линий. На основании животных, дата смерти которых известна, можно было установить, что период образования линий наступает от сентября до января (фиг. 3). Точное определение возраста возможно только если известно, в какое время года мускусный овцебык умер. Вследствие назначительной общей толщины цементного слоя невозможно оценить, как долго данное животное прожило после образования самой наружной ростовой линии, и если дата его смерти неизвестна, возраст его поэтому можно определить только как " N или N+1" лет, причем N равно числу ростовых линий. Старшим животным в материале была самка (застреленная в январе), возраст которой был определен как 14 лет 8 месяцев.

Практическое применение этих двух способов ограничено тем, что необходимо иметь в распоряжении мертвый материал. Однако, исследованием характеристики прорезывания резцов живых наркотизированных особей можно определять возраст животных, пока он не превышает прибл. 3 лет (табл. 3).

Разработаны рисунки стадий развития рогов особей предопределенных возрастных групп (табл. 1), и их можно использовать для определения пола и возраста мускусных овцебыков при полевой работе. Однако, развитием рогов с приемлемой степенью надежности можно руководиться только в случае животных возраста от 2-х до 4-х лет, в случае самцов может-быть и до 4 ½ лет.

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