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Epiphyseal fusion and tooth eruption in a population of feral goats from Moffatdale, Dumfries-shire, Scotland.

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The estimation of the age at death of an animal whose bones are recovered during archaeological excavations is considered to be one of the more important aspects of the osteological study of these remains. In any attempt to consider the importance of, or economic use to which domestic animals have in the past been put the age structure of the bone assemblage, i.e. the age at slaughter of the individuals represented in the collection, is fundemental.

High mortality in the early part of 1979 made available a collection of twenty five whole and partial skeletons of feral goat including their skulls, and a further seven heads, from Moffatdale in Dumfries-shire. The animals are mainly males and the cause of death in most was starvation during the long winter of 1978/79. The male animal considerably reduces feeding during the rut in September and October and the bacterial count in their rumen drops to such an extent that when feeding is resumed the breakdown of food is very inefficient and despite full stomachs the animals die if conditions in late winter and spring remain harsh. The nutrition level of the animals in this herd is much the same as the sheep flocks in the Border country, but the latter are fed hay at times during the winter. There has been a population in the area for o over one hundred years which has fluctuated in numbers and been supported at times by immigration from other herds (Whitehead, 1972).

Material

Half of the skeletons were prepared by boiling for three hours with sodium perborate ($NaBO_3.4H_2O$), cleaning by hand and subsequent reboiling for a further hour. The remainder were left on the hillside to decompose

naturally,protected from foxes and sheep dogs by cairns of stones, and were collected some six months later.These latter carcasses were then boiled for approximately one hour to clean the bones and complete the breakdown and separation of adhering tissue.The age of the individual animals has been assessed to within plus or minus two months. The details of the age of these animals has been furnished by David Bullock of Durham University,who has been studying the ecology of the population.He kindly went to the trouble of locating and collecting most of the carcasses.The kids in the population are born in late March or early April during a four week period(Bullock pers.comm.). Since the animals collected were of unknown birthday I have assumed all animals were born in March or April,and the ages estimated to the nearest month using March 31st as the time of birth.The time of death of most of the animals is determinable to within one month and the age in years is arrived at by counting the number of horn-sheath rings. Bullock(pers.comm.)has found that where the age of the animal is known the horn rings agree and none of the data presented below suggests that any estimates were incorrect.Geist(1966)found horn ring counts were valid for age estimation in male Bighorn sheep but erratic in the females.Sex was readily determinable from the skulls,but the females skeletons were of advanced age and no useful comparison could be made for males and females.

Results

Post-cranial skeleton

The fused,unfused or just fused(when the epiphysis cannot be separated without damage to the bone tissue)condition of the epiphysis of most? elements of the post cranial skeleton were recorded for twenty four goats whose approximate age was known.This is summarised in Table 1 in the approximate order of fusion of the twenty epiphyses each of

which is discussed below.Twenty of these animals were males and the remaining four female.In the discussion below of each epiphysis the ages of the youngest animal with its epiphysis just fused and the oldest animal with its epiphysis unfused are noted in months in brackets at the end of the entry.Since there are many ages unrepresented in the collection these figures cannot be interpreted as maximum and minimum ages of fusion.

1.Distal humerus.Unfortunately no animals of less than one year were found so this epiphysis was fused in all the specimens studied.Noddle (1974)notes one two year old feral goat from Rhum with this fusion line still visible,but this animal was afemale and since the majority of her fourteen animals from Rhum were female(9)it seems unwise to draw any comparisons between the populations.

2.Proximal radius.This epiphysis was fused in all specimens.

3.Scapula bicipital tuberosity.Two individuals of similar age,approximately 12 months,exhibited an unfused and a fused condition and one animal of 15 months had just fused.(12,12)

4.Innominate,main bones.The main bones of the pelvis were still unfused in two individuals of 12 and 15 months,but were just fused in an animal of 12 months.(12,15)

5.Second phalanx.The proximal epiphysis was unfused in all three one year olds but had fused in an animal of 34 months.Unfortunately no animals were present whose ages fell between 15 and 34 months.(34,15)

6.First phalanx. The proximal epiphysis was unfused in all one year olds and had just fused on animal MQ at 34 months.(34,15)

7.Distal tibia.Just fusing in an animal of 37 months,unfused in one of 34 months and fused at 46 months and all older animals.(37,34)

8.Proximal femur.The fusion of the head and trochanter major of the femur spanned some time.It was unfused in animals 34 and 46 months old, just fused in animals of 37 and 48 and completely fused in animals of

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Epiphyseal fusion data for the post-cranial skeleton:

Code	Sex	Age	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.
MAB	Male	1,00	F	F	F	J	U	U	U	U	U			U	U	U	U	U	U	U	U	U
MAD	Male	1,00	F	F	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
MAK	Male	1,00	F	F	U	U				U						U	U			U	U	U
MAJ	Male	1,03	F	F	J	U	U	U	U		U			U	U	U	U			U	U	U
MB	Male	2,10	F	F	F	F	F	J	U	U	U	U	U	U	U	U	U	U	U	U	U	U
MAA	Male	3,01	F	F	F	F	F	F	J	J	U	U	U	U	U	U	U	U	U	U	U	U
MP	Male	3,10	F	F	F	F	F	F	F	J	U	U	U	U	U	U	U	U	U	U	U	U
MR	Male	3,10	F	F	F	F	F	F	F	U	F	F	U		U		U	U	U	U	U	U
MAF	Male	4,00	F	F	F	F	F	F	F	F	J	J	U	J	J	U	J	U	U	U	U	U
MAC	Male	4,00	F	F	F	F	F	F	F	J	J	J	U	J	J	U	U	J	U	U	U	U
MU	Male	4,00	F	F	F	F	F	F	F	F	F	F	F	J	J	J	J	J	U	U	U	V
MM	Male	5,09	F	F	F	F	F	F	F	F	F	F	F	F	J	F	J	J	F	J	U	V
MW	Male	5,09				F	F	F	F	F		F	F	F	F					U	U	V
MN	Male	5,10	F	F	F	F	F	F	F	F	F	F	F	F	J	J	J	J	U	U	U	U
MY	Male	5,11				F		F	F	F		F	F	F	J					U	U	U
MAE	Male	5,11	F	F	F	F	F	F	F	F	F	F	F	F	J	F	J	F	F	J	U	V
ME	Male	5,12	F	F	F	F	F		F	F	F	F		F	J	J	J	U	U	J	U	V
MO	Male	6,00	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	J	J	F
MB	Male	6,10	F	F	F	F	F		F	F	F	F		F	F	F	F	J	F	F	J	V
MC	Male	6,11	F	F	F	F	F	F	F	F	F			F	F	F	F	F	F	J	J	F
MX	Male	6,11	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	J	J	V
MAG	Female	7,12	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	J	J	F
MZ	Female	8,00	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F
MAO	Female	8,03			F				F			F	F	F	F					F		F
ML	Female	10.08				F		F	F	F		F		F	F						F	F

F--Fused,completely fused,but fusion line still visible on some animals.
U--Unfused,epiphysis can be separated from the diaphysis without breakage of tissue.
J--Just fused,epiphysis cannot be separated and fusion has occurred for up to 3/4 of the circumference of the junction.
V--Vertebral epiphyses both fused and unfused;either posterior and anterior epiphyses on one centrum,or epiphyses on posterior and anterior vertebra.

Animals are all assumed to have been born in the period one month either side of March 31st.
The time of death of the animals is known to within approximately four weeks for all individuals.

48 months and older.(37,46)

9.Metacarpus.The distal epiphysis of the metacarpus was unfused in all animals up to 37 months and one of 46 months,just fused at 48 months and completely fused in animals of 46,48 months and older.(46,48)

10.Metatarsus.The distal epiphysis of this bone was unfused at 37 and 46,just fusing at 48 and fused at 46 and 48 months and older. (46,46)

11.Calcaneum.The proximal epiphysis is unfused in two animals of 48 months and fused in a third of 48 months.(48,48)

12.Distal femur.Unfused in an animal of 46 months but just fused in three animals of 48 months.(48,48)

13.Proximal tibia.Unfused in animals two of 46 ,just fused in animals of 48 to 72 months and completely fused in animals of 69,82 months and older.(48,48)

14.Distal radius.Unfused in two animals of 48 months,just fused at 48, 70 and 72 and completely fused in animals of 69,82 months and older. (46,48)

15.Proximal humerus.Unfused at 46 and one animal of 48 months,just fused in animals of 48 to 72 months and fused in older animals.(48,48)

16.Proximal ulna.Two animals of 46 and 48 months unfused and one animal of 72 months.Just fused at ages of 48 to 82 months and completely fused in animals of 71,82 months and older.(48.72)

17.Distal ulna.Epiphysis unfused in animals of 48,70 and 72 months, and completely fused at 69,71 and 82 months and older.(69,72)

18.Illial and ischial tuberosities.These tuberosities are unfused in animals of 70 and 71,just fused at 69 to 83 and in one female 96? months and completely fused at 82 months and in a female of 96 months.(69,71)

19.Left and right pubis fused.The innominate bones remain separate in all animals up to 72 months and are just fusing at 82,83 and in

a female 96 months,and completely fused in a female of 96 months and a second older.(82,72)

20.Vertebral epiphyses.It is difficult to catalogue the epiphyseal fusion on the vertebra since there appears to be a sequence of fusion. The epiphyses of the cervical vertebra fuse before the rest of the column and the anterior epiphysis before the posterior epiphysis on each centrum.The individuals were catalogued as unfused,partly fused (some epiphyses fused,others not),just fused(most epiphyses fusing) and completely fused.The vertebral epiphyses were unfused in most animals up to 71 months,with some epiphyses fusing in animals of 69 to 83 months. One male,MU,of 48 months had the vertebral epiphyses partly fused and individuals of 82,83 and all females of 96 and over had them all fused.(Youngest fusing-48;oldest fusing-83;oldest unfused-71;youngest fused-82months)

These epiphyses fuse mush later by comparison with the data sets for sheep(Silver,1969;Schmid,1972),and fusion of all post-cranial epiphyses is not to be expected in male animals of less than six to seven years in the Moffatdale population.There are observable differences in the order of fusion for the feral goats of Moffatdale and the order Noddle (1974)observed from a collection of individuals of different breeds. However since many of these differences are based upon only one or two specimens it is perhaps premature to discuss them in detail.Climatic factors such as the bad winters of 1977-78 and 78-79 and the summer droughts of 1975 and 76 may have influenced growth in this population; Noddle's animals had been through a period of mild winters,1968-72 (Noddle,pers.comm.).It is the intention to extend the present study to include two further feral goat populations from Galloway and Cheviot and with further material from these populations and Moffatdale a more? detailed comparison of different populations may be undertaken.

Cranial suture fusion and maxillary tooth eruption data

Twenty nine skulls,two of unknown age,have been collected from Moffatdale.Twenty two of these are from skeletons discussed in the previous paragraphs.The tooth eruption and an estimate of wear was noted for the maxillary teeth and the degree of closure(fusion)of seven of the cranial sutures on each skull and is summarised in Table 2.

Deciduous teeth were present in the three one year olds,and the second molar was unerupted and the crypt of the third molar unformed in all three.In a female of one year(?),MG,the deciduous premolars 1 and 2 had been shed,deciduous P4 was still in wear,M1 was in wear, M2 erupting and the crypt for M3 absent.At 24 months one animal had a visible but unerupted permanent premolar 2,a P3 half erupted and a P4 just coming into wear.The M1 and M2 of this animal were in wear and M3 is visible in the crypt but unerupted.By 34 months all the premolar permanent/teeth had erupted and were in wear but M3 was erupting through the bone of the crypt.In an animal of 37 months the M3 was erupted to half of its full height.An animal of 46 months still had the M3 unerupted but all animals of 48 months or over had their complete adult dentition.

Extensive wear was not observed on any teeth until an animal was 72 months old except for one animal of 48 months with unusually worn premolars and a second of 60 months.After 72 months most individuals show extensive wear of some of the premolar and molar teeth and in one individual,MC,of 81 months the M3 on one side had just been lost. Very heavy wear was only observed on females of eight years or over.

Fusion of the cranial sutures of the females occurred only in very old animals,one female of 96 months had the frontals half fused but no other sutures and a female of ten years had the frontal,nasal,

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Maxillary tooth eruption and cranial suture fusion data:

Table 2.

Code	Sex	Age	P2	P3	P4	M1	M2	M3	Frnt	Nas/Frnt	Nas	Frnt/Par	Fac/Zyg	Frnt/Fac	Par/Occip
MAB	Male	1,00	D	D	D	A	V	X	U			U	U	U	U
MAD	Male	1,00	D	D	D	U	V	X	U	U	U	U	U	U	U
MAK	Male	1,00	D	D	D	U	V	X	U	U	U	U	U	U	U
MAJ	Male	1,03	D	D	D	U	V	X	U	U	U	U	U	U	U
MG	Female	1,	S	S	D	A	E	X	U	U	U	U	U	U	U
MAH	Male	2,02	V	H	J	A	U	V	H			U	U	U	U
MQ	Male	2,10		A	A	A	A	E	H	U	U	U	U	U	U
MAA	Male	3,01	U	U	A	A	A	H	H	U	U	U	U	U	U
MP	Male	3,10	A	A	A	A	A	V	H	H	F	U	U	U	U
MAL	Female	?		A	A	A	A	U	U	U	U	U	U	U	U
MAF	Male	4,00	A	A	A	A	A	U	H	U	U	U	H	U	U
MAC	Male	4,00	B	B	B	A	A	A	F	F	U	U	U	U	U
MU	Male	4,00	A	A	A	A	A	A	F	F	F	F	U	U	U
MB	Male	5,00	B	B	B	B	A	A	F	F	F	F	H	H	U
MK	Male	5,09	A	A	A	A	A	A	F	F	F	F	F	H	U
MN	Male	5,10	A	A	A	A	A	A	H	F	F	F	H	H	U
MY	Male	5,11	A	A	A	A	A	A	H	H	U	U	H	U	U
MAE	Male	5,11	A	A	A	A	A	A	F	F	F	F	U	U	U
ME	Male	5,12	B	B	B	B	A	A	F	F	F	H	H	F	U
MO	Male	6,10	A	A	A	A	A	A	F	F	F	F	F	F	H
MD	Male	6,10	B	B	B	B	A	A	F	F	F	F	F	H	U
MC	Male	6,11	B	B	B	B	B	B*	F	F	F	F	F	H	H
MX	Male	6,11	A	A	A	A	A	A	F	F	F	F	F	F	F
MV	Female	7,?	B	B	B	A	A	A	U	U	U	U	U	U	U
MAG	Female	7,12	B	B	B	B	A	A	H	U	U	U	U	U	U
MJ	Female	?						B+	U	U	U	U	U	U	U
MZ	Female	8,00	B	B	B	B	B	B	U	U	U	U	U	U	U
MAD	Female	8,03	B	B	B	B	A	A	U	U	U	U	U	U	U
MAI	Female	10,02	B	B	B	B	B	B	H	U	H	U	H	H	U

D--Deciduous tooth;S--deciduous tooth just shed;
X--Crypt for tooth not present; C--Perforation in crypt not visible; V--Tooth visible in crypt but below head of bone;
E--Tooth erupting through bone; H--Tooth halfway between bone and full height;
J--Tooth just coming into wear; W--Tooth in wear but not all,or whole of,cusps;
A--All or whole of cusps in wear; B--Teeth well worn,wear surfaces flat; B+--extremely worn;
U--Unfused suture; H--Half fused suture; F--Suture fused for all or nearly all of its length.
*M3 of the left side has just been lost.

frontal-facial and facial-zygomatic sutures half fused.In the males the fusion of the cranial sutures approximately follows a sequence and spans about seven years and may prove of some assistance in estimating the age of skulls.

Frontal.The frontal suture is generally the first to close and is half fused or more in all individuals of 24 months or over.It takes some time to close completely and was still incompletely fused in one animal of 71 months.It was observed completely fused at its earliest in an individual of 48 months.

Nasal-frontal.The suture was half fused in an individual of 46 months and still only half fused in an animal of 71 months.The earliest complete fusion was on an animal of 48 months but one animal was still unfused at this age.

Nasal.The two nasal bones were rarely fused for more than half or less of their length and the youngest animal in which fusion had occurred was 46 months.But this suture was still unfused in an animal of 71 months.

Frontal-parietal.The suture between the frontal and parietal bones is first closed in an animal of 48 months,but still unfused in MY at 71 months and only half closed in ME at 72 months.

Facial-zygomatic.The facial and zygomatic bones were observed half fused at 48,70,71 and 72 months,three quarters fused at 69 and completely fused at 82 months and thereafter,but was still largely unfused in one animal of 71 months,MAE.

Frontal-facial.This suture is half closed in animals of 48,70,82 and 83 months and completely fused at 72 months in one animal.It is still open or just starting to fuse in two animals of 71 months.

Parietal-occipital.The parietal-occipital suture was the last of those observed to close and was first half closed in an animal of 82 months and fused in one of 83 months-the oldest male in the collection.This

suture was still unfused in one animal of 82 months.

Eruption and wear of the mandibular dentition

Owing to a delay in the recovery of some caracasses and the loss of teeth during boiling the rostral dentition of some of the mandibles is incomplete and an entry such as V in Table 3 indicating a tooth visible in the crypt may only be possible because the deciduous tooth has fallen out.

Incisors.The deciduous incisor 1 is present at 15 months but has been replaced by 26 months by a permanent tooth in wear.The dI2 was still present at 26 months but a permanent tooth in wear at 37.dI3 is present at 26 and a permanent I3 visible but unerupted at 37 months and unworn at 46 months.The deciduous canine(dI4) is still present in an animal of 48 months but has been replaced by a permanent tooth just coming into wear in another individual of 48 months.

Premolars.Deciduous premolars were present in all animals up to 15 months and P3 and P4 were half erupted in an animal of 26 months with P2 still below the bone.The premolar teeth became well worn with flat occlusal surfaces between five and six years,and P3 and P4 were lost in a female of eight years.

Molars.Molar 1 was in wear for all individuals and M2 at various stages of eruption in the one year olds and in wear by 26 months.M3 was erupting in an animal of 34 months and erupted but unworn in one of 37 months.Extensive wear with flattened cusps was not observed on M2 and M3 until eight years of age.

The mandibular and maxillary premolar teeth appear tp develope synchronously but in one animal,MP,the M3 was erupting considerably later in the upper jaw,the first two cusps of the lower M3 were in wear while the upper was unerupted.

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Eruption and wear of the mandibular teeth:

Table 3.

Code	Sex	Age	I1	I2	I3	I4	P2	P3	P4	M1	M2	M3
MAB	Male	1,00	D	D	D	D	D	D	D	A	E	X
MAD	Male	1,00	D	D	D	D	D	D	D	A	V	X
MAK	Male	1,00	D	D	D	D	D	D	D	A	E	
MAJ	Male	1,03	D	D	D	D	D	D	D	A	H	
MAH	Male	2,02	J	D	D	D	V	H	H	A	W	C
MQ	Male	2,10	A		V			W	A	A	A	E
MAA	Male	3,01	A	W	V		U	W	A	A	A	U
MP	Male	3,10	W	W	U	D	A	A	A	A	A	W
MR	Male	3,10	A	W	J							
MAF	Male	4,00	A	A	W	J	A	A	A	A	A	A
MAC	Male	4,00	A	A	W	D	W	A	B	B	A	A
MU	Male	4,00		W	J	D	A	A	A	A	A	A
MB	Male	5,00	A	A	A	A	A	B	B	lost	A	A
MAL	Female	?	A	A	J	D	W	W	A	A	A	W
MW	Male	5,09	A	A	A	W	A	A	B	B	A	A
MN	Male	5,10	A				A	B	B	B	A	A
MAE	Male	5,11	A	A	A	A		B	B	B	A	A
ME	Male	5,12	A	A	A		B	B	B	B	B	B
MO	Male	6,10	A	A	A	A	W	B	B	B	A	A
MB	Male	6,10					J	B	B	B	A	A
MC	Male	6,11	A	A	A	W						
MX	Male	6,11	B	B	A	A	W	A	B	B	A	A
MV	Female	7,?						B	B	B*	A	A
MAG	Female	7,12	B	B	B	B	W	B	B	B	B	A
MZ	Female	8,00	B	B			B	lost	lost	lost	B+	B+
MAO	Female	8,03	B	B	A	A	B	B	B	B	A	A
MAI	Female	10,02	B	B	B		B+	B+	B+	B+	B+	B+

D--Deciduous tooth; X--Tooth crypt not present; C--Perforation in crypt visible; V--Tooth visible in crypt but below head of bone; E--Tooth erupting through bone; H--Tooth halfway between bone and full height; U--Tooth almost at full height but unworn; J--Tooth just in wear; W--Tooth in wear but not all cusps,or whole surface of cusp; A--Whole surface of all cusps in wear; B--Tooth well worn,occlusal surface flat; B+--extremely worn.

B*--M1 lost in one jaw.

The ages of tooth eruption,suture closure and epiphyseal fusion have been outlined for a collection of feral goats from one population. It would be possible from this data to age skulls and skeletons of unknown age from Moffatdale to within six months of their actual age in most cases,but certain aspects of the sample must be repeated.The age estimates for the animals forming the basis of this study have a possible error of two months.For some months of the year the males of the population undergo little or no growth and indeed there is evidence from the skeletons that resorption of bone tissue has occurred in some animals,presumably due to their starvation.How significant this period is in terms of delayed developement is unknown.Few females have been studied and comparison of the developmental rate of the sexes has not been possible.In terms of archaeological material the data suggests that individual bones cannot be accurately aged,fusion of some bones occurring over a period of two years,and the observed range in the collection can only be taken as a minimum,except where age groups are missing,due to small sample size.The projected further analysis of other populations of feral goat may permit an assessment of the variation,if any,in the rate of skeletal development,and an increase in the size of the present sample may clarify the sequence of eruption and fusion.

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