Recent Advances in Ageing and Sexing Animal Bones

For Vasili and Marilena

Proceedings of the 9th Conference of the International Council of Archaeozoology, Durham, August 2002

Series Editors: Umberto Albarella, Keith Dobney and Peter Rowley-Conwy

Recent Advances in Ageing and Sexing Animal Bones

Edited by
Deborah Ruscillo

Oxbow Books

Published by
Oxbow Books, Park End Place, Oxford OX1 1HN

ISBN 1 84217

A CIP record for this book is available from The British Library

This book is available direct from
Oxbow Books, Park End Place, Oxford OX1 1HN
(Phone: 01865–241249; Fax: 01865–794449)

and

The David Brown Book Company
PO Box 511, Oakville, CT 06779, USA
(Phone: 860–945–9329; Fax: 860–945–9468)

and

via our website
www.oxbowbooks.com

Cover image: Ursus americanus baculum, mandible and innominate, photo taken by Haskel Greenfield

Printed in Great Britain at
Antony Rowe, Chippenham

Contents

Part IV. Applications of Osteometrics and Epiphyseal Fusion

Part V. Studies in Sexual Dimorphism

Preface

Umberto Albarella, Keith Dobney and Peter Rowley-Conwy

This book is one of several volumes which form the published proceedings of the 9th meeting of the International Council of Archaeozoology (ICAZ), which was held in Durham (UK) 23rd–28th August 2002. ICAZ was founded in the early '70s and has ever since acted as the main international organisation for the study of animal remains from archaeological sites. The main international conferences are held every four years, and the Durham meeting – the largest ever – follows those in Hungary, the Netherlands, Poland, England (London), France, USA, Germany and Canada. The next meeting will be held in Mexico in 2006. The Durham conference – which was attended by about 500 delegates from 46 countries – was organised in 23 thematic sessions, which attracted, in addition to zooarchaeologists, scholars from related disciplines such as palaeoanthropology, archaeobotany, bone chemistry, genetics, mainstream archaeology etc.

The publication structure reflects that of the conference, each volume dealing with a different topic, be it methodological, ecological, palaeoeconomic, sociological, historical or anthropological (or a combination of these). This organisation by theme rather than by chronology or region, was chosen for two main reasons. The first is that we wanted to take the opportunity presented by such a large gathering of researchers from across the world to encourage international communication, and we thought that this could more easily be achieved through themes with world-wide relevance. The second is that we thought that, by tackling broad questions, zooarchaeologists would be more inclined to take a holistic approach and integrate their information with other sources of evidence. This also had the potential of attracting other specialists who shared an interest in that particular topic. We believe that our choice turned out to be correct for the conference, and helped substantially towards its success. For the publication there is the added benefit of having a series of volumes that will be of interest far beyond the restricted circle of specialists on faunal remains. Readers from many different backgrounds, ranging from history to zoology, will certainly be interested in many of the 14 volumes that will be published.

Due to the large number of sessions it would have been impractical to publish each as a separate volume, so some that had a common theme have been combined. Far from losing their main thematic focus, these volumes have the potential to attract a particularly wide and diverse readership. Because of these combinations (and because two other sessions will be published outside this series) it was therefore possible to reduce the original 24 sessions to 14 volumes. Publication of such a series is a remarkable undertaking, and we are very grateful to David Brown and Oxbow Books for agreeing to produce the volumes.

We would also like to take this opportunity to thank the University of Durham and the ICAZ Executive Committee for their support during the preparation of the conference, and all session organisers – now book editors – for all their hard work. Some of the conference administrative costs were covered by a generous grant provided by the British Academy. Further financial help came from the following sources: English Heritage, Rijksdienst voor het Oudheidkundig Bodemonderzoek (ROB), County Durham Development Office, University College Durham, Palaeoecology Research Services, Northern Archaeological Associates, Archaeological Services University of Durham (ASUD), and NYS Corporate Travel. Finally we are extremely grateful for the continued support of the Wellcome Trust and Arts and Humanities Research Board (AHRB) who, through their provision of Research Fellowships for Keith Dobney and Umberto Albarella, enabled us to undertake such a challenge.

The present volume publishes the proceedings of the session 'Ageing and Sexing', which was among the first to be proposed for ICAZ 2002 and ended up being one of the strongest and best attended. This was in large part due to Deborah Ruscillo's excellent organisational skills, but also to the inherent interest and appropriateness of this subject for an ICAZ conference. Whether we study material from Argentina or Japan, from the Palaeolithic or the medieval

period, we still need to deal with the issue of ageing and sexing animal bones. A methodological session may be of little interest outside the field of zooarchaeology, but this is compensated for by the fact that *all* animal bone specialists will be interested in it. Initially Deborah wanted simply to find the best venue to present her interesting new method of sexing mammal bones through shape analysis. However, here was an opportunity to be more ambitious and organise a whole session dedicated to sexing and ageing studies. Things went ahead as planned and this book represents the culmination of almost three years of work, begun with a cosy conversation in the warm environment of the Ruscillo/Cosmopoulos home in Winnipeg (as the external temperature approached *minus* 30°C!).

The publication in 1982 of the volume "Ageing and sexing animal bones from archaeological sites", edited by Bob Wilson, Caroline Grigson and Sebastian Payne, represented a milestone in the development of zooarchaeological studies, and the book is, unsurprisingly, one of the most cited publications in zooarchaeology. Since then, as Terry O'Connor highlights in his introduction to the present volume, much more work has been done in refining ageing and sexing methods and in improving our understanding of body development and sexual variation in the vertebrate skeleton. However, so far zooarchaeologists are still by and large adopting ageing and sexing methods that are pre- rather than post- 1982. The challenge of this book is therefore not just to add more information, but also to persuade zooarchaeologists that the time is ripe for experimenting with new methods and for analysing data by taking into account the substantial new advances that this discipline has produced in more recent years. Only time will tell if this volume will have achieved this ambitious goal, but whatever the case, we have little doubt that it will represent an indispensable tool for zooarchaeologists worldwide.

Final special thanks must go to Vasili and Marilena Cosmopoulos (Deborah's son and daughter), who had the good grace to be born during the final stages of the editing of this volume. We could not have expected a better omen for the success of the book.

Acknowledgments

These proceedings are a direct result of the teamwork and collegiality of the authors involved. Always polite and accommodating, the participants of the Ageing and Sexing Session were a pleasure to work with, and I thank them for their cooperation and their contributions to methodology in zooarchaeology. The participants of the session also acted as referees of the published proceedings; each participant reviewed two papers submitted for publication to ensure the quality and accuracy of the information presented herein. For the sake of keeping costs low, raw data for the various studies presented in this volume could not be published. The authors are happy to provide raw data from their research upon request (addresses provided at the end of each chapter).

The session would not have been such a success were it not for the tireless support and direction of the conference organizers. This publication was made possible by these same individuals who also bravely took on the series editing and organization after the conference ended. On behalf of all the participants of the Ageing and Sexing Session, I wish to express our appreciation for the commitment of Umberto Albarella, Keith Dobney, Peter Rowley-Conwy and Deborah Jaques for the conference preparations and publication series organization. I would also like to thank Simon Davis and Caroline Grigson for chairing the morning and afternoon sections of the ageing and sexing colloquium, and also for acting as referees for some papers submitted here.

Travel and accommodation grants for the participants were supplied thanks to generous funding from the Institute for Aegean Prehistory (INSTAP). We are grateful for their support and their broad vision of archaeological research. INSTAP is one of the few organizations that realize the potential of zooarchaeological studies in the quest of studying ancient peoples.

9th ICAZ Conference, Durham 2002
Recent Advances in Ageing and Sexing Animal Bones (ed. Deborah Ruscillo) pp. 155–178

10. Tooth Eruption and Wear Observed in Live Sheep from Butser Hill, the Cotswold Farm Park and Five Farms in the Pentland Hills, UK

G. G. Jones

Following Deniz and Payne's work on goats (1982), 1611 observations of live sheep were made, to provide modern information useful in making age estimates in archaeological studies of husbandry and seasonality. Breeds studied were the Soay, Scottish Blackface, Shetland, White-faced Woodland, other traditional breeds and commercial crossbreds. Details are given of the tagging systems, date of birth, intervals of visits, practical difficulties, accuracy and grouping of stages. Figures show results for incisor eruption, and eruption and wear for dp4, P4 and the molar teeth. Overall results are summarized using Payne's mandible stages, sub-divided using wear on the most recently-erupted tooth. Results from different breeds show a general similarity for all sheep, with Blackfaces similar to the traditional breeds, but some Soays erupting late. Differences between sheep and goats are seen in dp4 wear and the order of eruption of P4 and M3. Relative wear on adjacent teeth is shown as a means of studying wear-rate, and hence adjusting age-estimates for mandible stages which depend on wear. Comparisons of wear-rate show differences between the study sheep, UK Romano-British to medieval sheep and Neolithic Greek sheep.

Introduction

The study of dental eruption and patterns of wear in the lower jaw of sheep is well established in zooarchaeology and is used to estimate age at death. This provides important clues concerning husbandry practices. The eruption of incisor teeth is used by farmers to give a general indication of age especially in young sheep, but the cheek teeth, being difficult to see, are not examined and there is little modern information on them. In excavated material it is the cheek teeth which are useful, as the teeth are deeply set within the jaw and survive well in contrast to the incisors, which are usually lost *post mortem*. Estimates of age at death have relied on old data, primarily those quoted by Silver (1969), which were based on Simonds (1854) and Brown (1860), on Payne's work on sheep and goats (1973), and Deniz and Payne's work on goats (1979, 1982). The problems are much discussed in the literature and are summarized by Moran and O'Connor (1994) in their study of dental and epiphysial fusion in aged sheep from museum collections.

Deniz and Payne studied tooth eruption and wear in live Turkish Angora goats, and their method was used in this study of British sheep. Observations were made on 1611 live sheep in three locations and of various breeds, including primitive and traditional. The primary aim was to provide modern information useful to the zooarchaeologist making age at death estimates, and inferring ancient husbandry practices and season of slaughter. Secondarily, information was sought on whether large differences could be seen between the groups of sheep examined, and whether results for these UK sheep were similar to those from the Turkish goats.

Materials

The sheep and farms

Sheep were examined in three places: at the Cotswold Farm Park (CFP) in Gloucestershire, at Butser Ancient Farm Project in Hampshire, and, via the work of the Animal Diseases Research Association, The Moredun Research Institute, at several hill farms in the Pentland

Farm	Breed	0–12 mo 1st year		13–24 mo 2nd year		27–36 mo 3rd year		42–60 mo 4/5th year		66–84 mo 6/7th year		Total	
		Rec	Ind	Rec	Ind	Rec	Ind	Rec	Ind	Rec	Ind	Rec.	Ind.
Butser Ancient Farm	Soay	186	48	98	24	66	13	50	9	19	3	419	65
641 observations	Shetland	46	11	7	2							53	11
of 107 sheep	Hebridean	27	8	18	3	23	4	13	4			81	14
	Manx Loghtan	13	3	6	2	6	2	6	1	3	1	34	6
	Mouflon	7	2	7	2	1	1	7	1	2	1	24	4
	Mouflon x Soay	4	1	2	1							6	1
	Soay x Suffolk	17	6	7	2							24	6
BAF of uncertain age 194 of 27[1]	14 Soay, 13 others												
Cotswold Farm Park	Whitefaced Woodland	38		52		27		14		2		133	80
488 observations	Shetland	24		55		25		19		1		124	54
of 337 sheep	Jacob	16		20								36	33
	Other minority breed	12		14		15		18		9		68	62
	commercial cross	32		38		4		20		33		127	108
Pentlands: hill farms	Scottish Blackface	32		41		34		67		45		219	[2]
Pentlands: lowland	Scottish Blackface	18		10		8		32		1		69	
288 observations													
Total		472		375		209		246		115		1417	

Rec. – records; Ind. – individuals; [1] - not included in the main study, but used in the reversals study; [2] – not individually tagged.

Fig. 1. Number of observations, and number of individual sheep seen, in each year class.

Hills south of Edinburgh. The breeds seen and number of observations are shown on Fig. 1, a total of 1417 observations of known-age sheep on which this study is based. A further 194 observations of older sheep at Butser were of uncertain age; but these results were useful for studying errors (see below). Nearly all sheep over a year old were ewes (825 records of ewes, 65 of rams, no castrates).

The CFP is on limestone, and the sheep had access to extensive good quality grazing with some winter feeding of hay and concentrates. The breed seen most regularly was the White-faced Woodland, with further records of unimproved coloured Shetlands, Jacobs and commercial crossbreds, plus occasional records of Hebrideans, Welsh Mountains, Orkneys, Herdwicks and Manx Loghtans. Visits were three-monthly. The commercial sheep were mostly second generation crosses, of (Swaledale x Colbred) x Colbred, or Mules (Swaledale x Blue-faced Leicester) x Colbreds.

At Butser, on the chalk South Downs, pasture was sufficient but more restricted. Some sheep were kept for part of the time in the grounds of Fishbourne Roman Palace. Where necessary, winter feed was given as hay with some concentrates. Sheep examined were Soays, and a smaller number of unimproved Shetlands, Manx Loghtans, Hebrideans, four Mouflons and one Mouflon x Soay. Visits were monthly.

Two visits were made to Scotland, joining John Spence's group studying premature incisor loss ('broken mouth'). The sheep, all Scottish Blackfaces, were on hill farms with extensive rough grazing of heather and grass, with extra feed of hay and/or fodder crops in bad conditions in the winter and at lambing time, and with access to low ground fields before the rams are introduced in November. In addition, on two occasions when the weather was too bad for the hill sheep to be brought down, some Blackfaces belonging to the Moredun Institute were seen. These were maintained on low ground pastures with extra feed over the autumn/winter and lambing period in the form of concentrates and roots, and may also have been put in a turnip field. This last area will include high silica/soil uptake.

Tagging and date of birth

At CFP, 360 of the records are from sheep whose age was known to the day. Sheep bore a lambing tag whose first digit represented the year, and usually also a breed registration number tag. Some other sheep (65 records from commercial sheep and 58 from other breeds) were also recorded where their age could with confidence be assigned to one age class; most (72%) were in the age classes which last three or six months. Date of birth could usually by deduced from the lambing tag. Tags were used sequentially, so that a tag of 5101 born on 16/03/85 and a tag of 5113 born on 18/03/85 (both flock book sheep) give a close estimate for tag 5111 (a commercial sheep not written down).

At Butser, day of birth was known for the sheep born during the period of study (1984–87). When a tag was lost, the sheep was retagged with a new number, and the identity could be deduced by elimination plus previous descriptions of colour, etc. Tagging and records were good for some of the Butser pre-1984 born sheep and in a few others, the year of birth was obvious and the age was estimated. Records were made of some older sheep of unknown age and a note of results is made separately.

The Scottish sheep were horn-branded with the year

of birth. Births are mostly between 10th April and 10th May. The two visits of 11–14th September and 19–21 March give estimated ages two or three weeks either side of 4.5 months and nearly 11 months plus the age in years obtained from the horn-brand (0, 1, 2,...6 years).

The rams ran with the flock all year at Butser, so lambing time followed a natural pattern. In 1985–7, 57 Soays lambs were born between 29th March and 22nd May with a mean birth date of 17th April. These birth-dates are very close to those recorded by Jewell *et al.* (1974) for St. Kilda Soays, where the mean birth date was 15th April (491 sheep observed over three seasons). Thirty-seven other Butser lambs (Shetlands, Manx Loghtans, Hebrideans, the Mouflon and the Mouflon x Soay) were born between 17th March and 24th April with a mean of 8th April. Births at CFP were somewhat earlier, 11th March to 19th April, with an average of 31st March (N 188)(excluding the commercial sheep).

Method

The method used to record the teeth is described by Deniz and Payne (1982) (and see Plates 1.16 and 1.17 in Davis 1987). The sheep was held by a helper. Records were made of the incisor teeth present, in addition to the wear on the occlusal surface on the left side. The mouth was then held open by placing the speculum (a copy of Payne's original design) in the diastema. A Twinlite torch with fibre-optic, spatula-shaped attachment kept the tongue away from the teeth and provided light in the mouth. The left mandibular teeth were cleaned and recorded with the help of a dental mirror attached to a second Twinlite.

The speculum was used for all the Scottish examinations, the larger breeds from three months, and all breeds (other than Soays) from six months. With the Soays, the smallest breed, a smaller speculum was used. In some cases, the mouth was large enough to use the speculum at five months; at nine months, it could be used in two-thirds of the specimens; it was used in most by eleven months and in all by twenty months.

For young lambs the speculum could not be used and the jaw was held open by placing the left fingers in the diastema. The jaw did not open sufficiently to use the dental mirror, so observations were made directly. This meant that the base of the V between the three elements of the deciduous fourth premolar (dp4) was difficult to see in cases where the cusps in front of the V were still high, thus obscuring the base.

The amount of light in the mouth was variable. On a sunny day, the light behind was a help. On cloudy days working outside, the light given by the torches was less useful than when working in a barn where the eyes were better adjusted to torchlight.

For incisor teeth, both eruption (of both left and right sides) and wear (left only) were recorded but only eruption has been summarized here. The stages used (Figs 8 and 10) show how many permanent incisors were present (right plus left) in usual agricultural practice. In the stage 'two-tooth', both first incisors were at full occlusal height (but not necessarily showing dentine wear). In the 'E/H/one' stage, the right and/or left side was erupting or half up, or one only was at full height.

The stage 'not yet erupted' means not erupted into the mouth cavity, 'E' means just through the gum line, and 'H' means about halfway between the gum and full height. 'E' and 'H' are therefore more advanced than Ewbank *et al*'s (1964) codes for archaeological specimens. 'J', enamel wear only, is a very brief stage for sheep, and has been joined with 'E' and 'H'. The phrase 'in wear' has been used to mean that dentine has been exposed on the tooth. This practice follows Payne (1973, 293) and is often used for sheep, cattle and deer; note, however, that it should not be extended and applied to pigs, where the enamel is much thicker, and the definition of 'in wear' should begin at the 'enamel wear only' stage. The wear stages (Payne 1973 and 1987) record numerically the four aspects of progressive tooth wear: initial dentine wear on each cusp, the number of dentine joins between cusps, the long-lasting mature wear stage (9A for M1 and M2, 11G for M3, 14L for dp4) and, as the tooth wears to its base, the gradual erasure of the dental infundibula, the 'islands' of enamel.

The visits were made entirely through the generosity of the various organisations, and the specimens examined were what were possible and practicable, which was not always ideal; e.g., at CFP sometimes a particular group were grazing some miles away from the handling pens and were not seen; sometimes it was convenient to see the smaller groups of sheep on display to the public and not the whole group of a breed. The two Scottish visits occurred during the Institute's fieldwork which did not match well the already-established 3, 6, 9 months for visits to CFP. Visits were not made at lambing time but were made a month later. Because date of birth was known, one visit at CFP gave results for more than one month class.

The age classes used were as follows: 0 (birth to 15 days), 1 month (16 days to 1 month, 15 days), 2 months (1 month, 16 days to 2 months, 15 days), and so on up to 22 months. For the third year, three-month classes were used: 24 months (22.5 to 25.5 months), and so on. For older sheep, six-month classes were used: 36 months (34.5 months to 39 months, 0 days), 42 months (39 months, 1 day to 45 months, 0 days), 48 months (45 months, 1 day to 51 months, 0 days), and so on.

The data were recorded in notebooks, and then onto a computer using a Microsoft Access database.

Note, on the tables summarizing results for each tooth, that the distribution in the columns, which shows the range of stages seen in sheep of a particular age, gives more reliable information than the distribution in the rows – the ages at which a particular stage was seen. The latter is the more interesting of course, but it is affected

by differences in sample size, composition (e.g. no CFP sheep of 0, 1, 2, 5, 11 or 12 months were seen) and independence. Results for CFP and Scottish Blackfaces are independent or nearly so, but at Butser, particularly at the later ages, many records are from a few individuals. A simple approach has been taken with the presentation of results, with the sample size directly shown. On Figs 3 to 9, the stage which includes the median value, where half the values are at or before and half or at or beyond this stage, is bold and underscored. The central two-thirds of the columnar distribution approximates to 1 standard deviation. Outlying results are not given undue emphasis in the discussion; the outlying 1 in 20 values approximate to those beyond two SD.

Descriptions of teeth follow Hillson (1986, 11 and 19–20) in the use of 'element' for the pairs of molar cusps, 'infundibulum' for the island of enamel, and lingual/buccal for tongue/cheek side. For sheep cheek teeth, the use of anterior and posterior (towards the front or back of the jaw) is equivalent to mesial and distal. For the third part of M3 (the hypoconulid, Hillson, Fig. 3.1), the 'posterior cusp' (when describing initial wear) or 'element' is used.

Mandible stages

With archaeological samples, it is usual to group the mandibles into stages based on eruption and wear, e.g., Ewbank *et al.* 1964, Higham 1967, Payne 1973, Grant 1975, 1982, Bourdillon and Coy 1980, O'Connor 1991, allowing the data to be shown on a single table or figure. The sheep studied here are summarized using Payne's stages, which do not depend on aspects of development (for example Ewbank's stage 'tooth visible in the crypt') which cannot be seen in the live animal. Because the sample sizes are substantial, and the duration of some of Payne's stages is quite long, the stages were subdivided. In an archaeological sample with, for example, many mandibles at stage C (M1 in wear, M2 not yet in wear), it is of interest to know if most are early within the stage, or late, or well-spread. The study of sheep at the Romano-British temple at Harlow is an example (Legge 1985). By drawing the typical 'A,B,C...I' histogram larger, and using a horizontal line within the stage C bar, the proportion at each M1 tooth wear stage could be shown, grouped according to the appropriate level of detail for the site and sample. The late mandible stage 'I' is renamed as 'J' in this paper, because of its greater legibility ('I', particularly in sans serif fonts, may be confused with the numeral '1').

The subdivision of stages used for the overall summary and the breeds summaries were based on the spread of stages by age observed for each tooth. Stage C was subdivided into C1/2, C3/4, C5 and C6+ using the wear stages of M1. Stage D (M2 in wear, M3 not yet in wear) was similarly divided using the wear stages of M2. Stage E was given two stages, E1/2 and E3+, using the wear on the first element and then the second element of M3. Stage F, where the posterior element of M3 is in wear, is divided into F5/8 and F9/10, using the wear on M3. Stage G has been subdivided on the basis of wear on M1, Ga where M1 is at 9A and Gb where any part of the infundibula of M1 are worn away.

There is a case for making the final subdivision of stage C to be 'M1 in wear, M2 E/J' (erupting, half up or just in enamel wear)(abbreviated to 'Cej'), and similarly for stage D ('Dej'). 'Dej' is the same as O'Connor's 'Subadult 2' (1991). For the study sheep, it was decided that the quality of data for C5 and C6+ was better than for E/J (more easily seen in the live animal), and there is a difference of meaning for 'E' between live sheep and archaeological specimens. There is an archive version of Fig. 9, using C5+ and Cej as the final subdivisions for C, or results can be calculated using Figs 9 and 5 (plus Fig. 6 for calculating D5+ and Dej).

Results

Stages used, and grouping of stages

Recording of the teeth present, the initial, the mature wear and the late wear stages proved on the whole reliable (see Accuracy, below), but the intermediate stages where dentine becomes gradually continuous between cusps were more difficult. The length of time that the head of the sheep was stationary was usually short and always the first few seconds were taken with identifying which cusp belonged to which tooth. Determining whether the dentine exposed on a tooth is continuous between cusps is a procedure normally done on dry archaeological material with a hand lens. Although the spatula-shaped Twinlite kept the tongue away from the teeth, and the second mirror kept the cheek away from the teeth, saliva produced by the papillae (see Weinreb and Sharav 1964, Fig. 7) was a problem. Drying with a cloth was tried, but moisture returned very quickly.

Many of the records could be given only to a range of stages. For example, many were recorded as either 4A or 5A, and in these the dentine was nearly, or just, continuous at the anterior edge, i.e. they were late within stage 4A or early within stage 5A. The grouped stages were frequent for the third molar, even to three or four stages. These grouped stages are safely within the second major stage between initial wear and the mature-wear stage. They were not, therefore, excluded, which would have altered the calculation of the median value. The grouped-stage records are sometimes numerous and show a spread of age classes as expected, see 8A and 8/9A for M2, 84 and 74 records respectively. Levitan (1982, Fig. 4, 213) shows the difficulty clearly. A few grouped results for P4 were excluded (see Fig. 7).

For the deciduous fourth premolar, dp4 the many stages between initial wear on all six cusps, 6L, and the

		dp4		**P4**		**M1**	**M2**		**M3**
No. of observations		408		365		773	635		409
No. of reversals		16		28		19	24		22
Percentage of reversals		*3.9%*		*7.7%*		*2.4%*	*3.8%*		*5.4%*
Early wear stages	nye to 6L	0	nye to 2A	0	nye to 4A	2	1	nye to 4A	5
Intermediate wear stages	6L to 14L	0	2A to 12S	21	5A to 9A	9	22	5A to 11G	17
Late wear stages	14L to 22L	16	12S to 15A	7	9A to 15A	8	1		
Adjacent stages		7		12		9	16		8
Two stages apart		7		5		5	6		10
More than two apart		2		11		5	2		4
Average interval between observations with reversal		2.25 mo		3.17 mo		3.70	2.90		2.46 mo

These include the older Butser sheep of uncertain age seen more than once. nye – not yet erupted.

Fig. 2. Reversals in 773 observations of 105 Butser sheep seen more than once.

mature wear stage, 14L (6 cusps in wear + 8 dentine joins = 14), were grouped into fewer stages. For example, the stage 7/10K (6 cusps + 1 to 4 joins), with two dots shown between the first and second pair of cusps, includes records where dentine was partly continuous at this point (e.g. 8L). It also included records where there was uncertainty: to quote a field note 'they're quite close to through, but the dentine narrows so that I can't be sure'. A more detailed study of the stages observed could be done from the archive record. The erasure of the anterior infundibulum of dp4 is gradual, and is defined as 16L when 'the length of the island (including the enamel) is less than 50% of the length of the lobe' (Payne 1973, 289). An intermediate stage, 15K, was added for cases where the anterior element was already wearing flat and the infundibulum was reduced in size, but before 16L.

Similarly, for P4 a stage 13S was added, between 12S and 14S. 13S should be included with 12S for comparison with archaeological records. A stage 5/12W was used for records where the anterior infundibulum was isolated, but the wear on the posterior part of the tooth was uncertain.

For molar teeth, the stages 6A/7A (7G/8G for M3s with the posterior cusp in wear) was combined throughout. This stage change depends on seeing clearly the bottom of the V-shape at the central part of the tooth, whereas for distinguishing 5A from 6/7A, 6/7A from 8A and 8A from 9A, the dentine join is at the lingual edge of the tooth and is easier to see.

Stages 1A and 2A were combined for simplicity, as were 3A and 4A. Neither 1A nor 3A were common. Cases of 1A and 1/2A (uncertain whether 1A or 2A) were 4 and 1 for M1, 2 and 0 for M2 and 10 and 4 for M3. Cases of 3A and 3/4A were 4 and 0 for M1, 8 and 0 for M2 and 7 and 2 for M3.

Within the six months of the later age classes, individual Butser sheep were seen several times, and a tooth may have passed through two or more stages, or it may have remained at one stage giving several records. (Theoretically this could be as many as six, but a maximum of four was used).

The results for Scottish Blackfaces at 4.5 months were allotted randomly to the adjacent age classes 4 and 5 months, half each, and, similarly, the 10.75 months to 10 and 11, quarter/three-quarters each, and so on for later age classes. They are shown separately, however, on Figs 11 and 12 in the Appendix below.

Accuracy

At Butser, 78 sheep of known age were seen more than once (579 records), and the development of individual sheep could be followed. A further 194 observations of 27 older sheep of uncertain age were recorded at Butser, and these are included here as they give information about later stages, making a total of 773 observations of 105 sheep.

This provided a useful check on accuracy. For example, if a sheep was recorded as showing an earlier stage than that recorded previously, the apparent 'reversal' indicated an error. Reversals are summarized on Fig. 2. They were fewest for M1 and increased, as would be expected, for the more distant M2 and then M3. Reversals for dp4 were all at later wear stages and indicate some inaccuracy in describing the erasure of the infundibula. Reversals were high for P4 and cast doubt on the validity of the P4 records as a whole. The tooth is of a more irregular shape than either dp4 or the molars, and frequently the posterior part of the tooth was difficult to define. In particular, in sheep of the age where dp4 is replaced and P4 comes into full wear, the primary focus of attention was the eruption and wear of the molars, and probably less time was spent on dp4/P4.

Most reversals were between adjacent stages, using Payne's numerical coding, e.g. 9A recorded and 8A on a subsequent visit, or two stages away, e.g. 8G to 6G in M3. The average interval between observations where there was a reversal was 2.25 to 3.70 months. The overall proportion of reversals was 4.21%.

Reversals were used unchanged in the summaries, except in the following two situations, where the record was treated as 'no data'. Firstly, in a few cases the reversal

followed three or more previous observations of the later stage. Secondly, in five records, reversals suggested that a tooth was wrongly identified. In one case, for example, three consecutive records give: dp4 15K, 16L and 18P; M1 9A, 8A and 9A; M2 5A, 5A and 6/7A; and M3 2A, not yet erupted and 3C/5A. That is, it is likely that the middle of these three records has mistaken the posterior pair of cusps present as the posterior part of M2 rather than the anterior part of M3.

Reversals were only slightly higher for Soays, than for Butser other breeds, despite the narrower speculum gap (4.42% for all four cheek teeth, and 4.01%, respectively).

There is a greater likelihood of error with the sheep records than with Payne's goat records, where there was only one reversal for cheek teeth in 367 observations of goats seen more than once (although far fewer goats were seen repeatedly than here). The goats studied had long horns, so that it was possible to hold the animals still. The sheep studied were mostly without horns. It was hoped that the horned breeds (Blackfaces in Scotland and White-faced Woodlands at CFP) would be a little easier to hold, but their horns were not long enough to exert much leverage. The ease of holding depended rather on body weight, so that the smaller breeds were in this respect easier, and in practice the White-faced Woodlands were large and very strong. Quite often the Soays would just give up and stand still. The speculum gap used for the sheep was smaller than that used for the goats. In the goat kids, the speculum could be used in all cases.

First year

During the first year, the increase in stage with age (Figs 3 and 4) can be seen, with the median value showing a regular pattern. For dp4 and M1 in three-quarters of the age classes, half or more records were at a single stage. After the first few months the span of ages at which a stage was observed increased, often to several months.

In six day-old lambs and one 5-day old, all three deciduous premolars could be clearly felt though they were still under the gingival membrane, which was very thin. Dp4 was a little higher than dp2 and dp3 but all were certainly above the alveolar bone, and might score 'half up' or 'up and unworn' in an archaeological specimen. In another day-old and two five days old lambs, the middle pair of dp4 cusps were through the gum, and in a lamb 'about six days old' all dp4 cusps were through but unworn.

At age class '1 month' (16 days – 1 month, 15 days), dp4 was unworn or at early wear stages, and by two months (1 month, 16 days – 2 months, 15 days) all dp4's observed were in wear, with most showing wear on all six cusps, 6L. By three months all had reached 7L and many were at later stages. At four and five months, the stages where dentine gradually becomes continuous between cusps predominated. By six months the anterior infundibulum was isolated in all cases (with one possible exception, at 7/13K), and the mature wear stage 14L was the commonest stage observed; this continued at seven and eight months. At nine months, not many cases were pre-14L and already a few showed some erasure of the anterior infundibulum.

In Fig. 15 in the Appendix, the wear stages of dp4 are shown against those of M1. At M1 stage E/J, most dp4 records were at 7L. Higher wear scores for dp4 may indicate fast wear, or the presence of goat, particularly if other characteristics of goat are present (Payne 1985), see below under 'Relative wear and Sheep/goats'.

Eruption of the first molar was seen to occur over a very short time, with none in wear at two months, a large group erupted or in enamel-wear, and many already in wear, at three months (2 months, 16 days – 3 months, 15 days) and most at wear stage 1/2A at four months. The few cases of M1 not yet in wear at four and five months were all Soays (see Fig. 11 in the Appendix). Stage 1/2A was observed in a third of the results at three months and more than half the results at four and five months. The later stage 3/4A, where the posterior element of M1 comes into wear, included more than half the results at six and seven months. This notable difference between 1/2A and 3/4A is the basis for dividing the mandible wear stage C into C1/2 and C3/4, used in the overall summaries. Results suggest that it takes a little over two months for M1 to move from initial wear to wear on all cusps, i.e., stage 4A.

Joining of the dentine at the anterior edge of the tooth (5A) was common from six to nine months, and at eight months the median value was at 5A. Note that at eight months, there was a spread of stages observed from 4A to 6/7A. At nine and ten months, more than half of records were at 6/7A. 9A was reached in a very few cases before twelve months.

Eruption and wear of the second molar is shown on Fig. 5. M2 was erupted but not in wear (E/J) in less than half of cases observed at nine months and more than half at ten months. At both 10 and 11 months the median value was at E/J, i.e. at ten and eleven months less than half had reached Payne's mandible stage D, M2 in wear. In the 11 months group of Blackfaces, half were in wear. No CFP sheep were seen at 11 or 12 months because of lambing time. By 13 months 1/2A was the most frequent stage and with almost as many at 3/4A. It is a reasonable deduction that at 12 months the median value would have fallen at 1/2A, with a reasonable number still at E/J, had more sheep been seen. Eruption for M2 was given as 9-12 months by Silver (1969). The coming into wear, the beginning of Payne's Stage D, can be given as 10–13 months, from this study. Eruption into the mouth cavity had occurred during the winter and the tooth was in occlusion, ready for the new grass of spring.

The stage E/J, 'erupted but not in wear' was frequent over the four age classes 9 to (presumed) 12 months (8 months, 16 days – 12 months, 15 days), which is much longer than for M1 where only at 3 months was it

Dp4 Stages	Years Months	0	1	2	3	4	5	6	7	8	9	10	11	1 12	13	14	15	16	17	18	19	20	21	22	2 24	27	30	33	3 36	42	48	54	5 60	66	72	78	84	
nye/U/J		**12**	12																																			24
2-4			**18**	2																																		20
6L			2	**15**																																		17
7L			4	9	**25**	4																																42
7/10K					**10**	2																																12
7/13K					7	**16**	13	1																														37
10N					3																																	3
10/13K					2	9	**15**	10	9		1																											46
13L					3	5	3	4	7	5	1				1																							29
10/14K						1	5	5	**8**	6	1																											26
13/14L							3	7	2	**7**	5																												24
14L						1	2	**30**	13	**18**	**28**	**26**	**23**	2	**31**	**23**	7	14	13	5	10	1	3	1		1		1										253
15K 'going'											2	9	4		6	9	1	**7**	**3**	1	**5**	2	2			1												52
16L									1			4	5	2	16	6	**5**	11	6	**11**	7	**4**	**10**	6	2		1											97
17 1 or ½+½ er.											1		5		5		3	5	3	3	2		**4**	5	3	2		1										42
18/19 1+ or 1½ er.													2				1	1	3			2	3	4	3	5	1	1										26
20 2 erased													2		1		1	1	2	3	1		4	1	6													22
21/23 2+ to 3 er.																1			1		2		1	**3**	6	1	2											17
shed and P4 nye																					1		2	1	2	1												7
P4 E/H																						1	1	6	**13**	4	4	3										32
P4 U/J																								3	7	**9**	7											26
P4 in wear																								5	3	21	**38**	**36**	51	87	40	67	35	47	23	26	3	482
P4 shed																																		2	1	3	2	8
Total		12	36	26	50	38	41	57	40	36	39	39	41	4	60	39	18	39	31	23	28	10	30	35	45	45	53	42	51	87	40	67	35	49	24	29	5	1344

Except where shown, the tables combine results from all sheep; nye – not yet erupted; U/J – all stages from unworn to just enamel wear; wear stages are defined in Payne 1973 and 1987, with additional stages suffixed K described under Method; er. – erased.

Fig. 3. Dp4 eruption and wear stages, and P4 eruption, by age class.

M1 Stages	Years Months	0	1	2	3	4	5	6	7	8	9	10	11	1 12	13	14	15	16	17	18	19	20	21	22	2 24	27	30	33	3 36	42	48	54	5 60	66	72	78	84	
nye		**12**	**35**	**22**	6	2																																77
E/J				3	**28**	3	1																																35
1/2A					17	**29**	**27**	3	4																														80
3/4A						4	10	**30**	**24**	4	3																												75
4/5A							1	14	8	11	2	2																											38
5A							1	11	2	**7**	8	5																												34
5/7A										5	**7**	9																											21
6/7A	/								1	9	19	**19**	18		1			2	2																				71
6/8A												1	**9**		6								1																17
8A													6	**3**	**31**	15	**11**	16	**15**	8	5	4	13	9	3	6	1	1											147
8/9A													4	1	10	**15**	5	**8**	10	2	8		**4**	1				1				1							70
9A												1	3		13	9	3	13	5	**11**	**14**	**7**	13	**23**	**42**	**38**	**47**	**43**	**53**	**85**	**37**	**45**	18	**26**	5	7	1	562
10A/B																																3			1	3			7
11A/B																														1	2	1	**2**	2					8
12A																														1	3	15	13	16	**6**	**10**	**2**		66
13A																																				1			1
14A																															1			2	**1**	1			5
15A																																2	4	3	8	6	**2**		25
shed																																		2	3		1		6
Total		12	35	25	51	38	40	58	39	36	39	37	40	4	61	39	19	39	32	21	27	11	31	33	45	44	48	45	53	87	43	67	37	51	24	28	6	1345

Stages are defined by the codes, with the diagrams shown at the main stages as an *aide-memoire*.

Fig. 4. M1 eruption and wear stages by age class.

frequent.

No incisor replacement was seen before 13 months, although in a few individuals, the deciduous incisor was shed at 11 months (Fig. 8).

Second year

During the second year, the span of tooth wear stages seen in each age class is greater, and the spread of ages at which a given stage was observed is great, but there are several age classes where the majority of values are at

M2 Stages	Years Months	0-6	7	8	9	10	11	1 12	13	14	15	16	17	18	19	20	21	22	2 24	27	30	33	3 36	42	48	54	4 60	66	72	78	84	5	6	7	
nye		263	41	**35**	**28**	14	6																											387
E/J				2	12	**17**	**19**		6																										56
1/2A				1		6	12	2	**26**	4																									51
3/4A						1	3	2	22	14	**10**	13	12	3	2	1		1																	84
4/5A							1		3	**16**	4	**8**	**7**	2			1	1		1															44
5A									3	3	2	9	6	**9**	7	4	1	2	1	1															48
5/7A									1			5	4	1	**5**	**3**	1	1	3	4	1														29
6/7A	/									2	1	4	3	7	12	3	**21**	**16**	**21**	11	10	8	4	3		1									127
6/8A																	1	3	3	2	2	3	2	1											17
8A														1			1	6	8	**9**	**15**	**11**	14	16	2	1									84
8/9A																		1	6	7	5	**11**	**13**	**20**	6	1									70
9A																	1			6	14	11	16	39	**34**	**63**	**35**	**50**	**21**	**28**	**4**				322
12A																														1		1			2
15A																															1				1
Total		263	41	38	40	38	41	4	61	39	17	39	32	23	26	11	27	31	42	41	47	44	49	79	42	66	35	50	22	29	5				1322

Fig. 5. M2 eruption and wear stages by age class.

a single stage. The span of ages for stage E/J increased from four months for M2 to six months for M3. The span for wear stages was greater, but not always by very much. The mature wear stages (14L for dp4 and 9A for M1), where crown height is gradually reduced without change to the pattern of dentine and enamel seen at the occlusal surface, is obviously long-lasting, but the pattern 'some have reached it', 'more than half have', 'the most frequent stage', 'more than half are beyond', is regular and progressive.

For dp4, more than half the records were at stage 14L from 9 until 14 months. The stage 15K 'going' (defined in 'Stages used', above) should be regarded as within 14L, for comparison with archaeological results using Payne's stages. From 15 to 19 months the median value varied between 15K and 16L. From 20 months on, more than half showed some erasure of the infundibula. Erasure of half or one infundibulum was common, but of two or more was unusual. At 22 months, some replacement of the deciduous tooth by the permanent fourth premolar was beginning, with a few cases of P4 already in wear.

For M1 during the second year, stages before 8A were unusual. 8A was the most common stage until 17 months although stage 9A was already quite frequent by 13 months. Only by the end of the second year was 9A nearly universal. The posterior fold separating the distal pair of cusps reaches quite deeply into the tooth, so that quite a lot of crown height is lost before 9A is reached. (No information is known to the author about the variability in the depth of this fold).

For M2 the age-spread for early wear stages, as with eruption (noted above), was much longer than for M1 at similar stages. Wear on the anterior cusps only (1/2A) was common from 10 to 13 months with a few earlier and later. Stage 3/4A was common from 13 (and probably from 12 months, see above) to 17 months. From 14 to 19 months the stages 4A to 6/7A predominate. At 21 to 27 months the most frequent record was stage 6/7A. Towards the end of the second year, stages beyond 6/7A occurred but were unusual (some Blackfaces at 23 months).

First signs of third molar eruption were seen at 18 months, with a few in wear at 19 and 20 months. At 21 months, more than half were erupted and by 22 months more than half were in wear. As with the second molar, the eruption of M3 appears to be linked to the seasons, the tooth being in occlusion by the spring, that is, at the beginning of the animal's third year.

For most breeds, the first incisors erupted and came into occlusion at 13 to 16 months (Fig. 8). Most of the later records are Soays and Mouflon (including 9 of the 11 at 17 months with di1 still present). Considering all breeds together, at 21 and 22 months there were a few cases of the permanent first incisor still unerupted, and a few with some eruption of the second incisor. This is a much greater variation than seen in molar eruption.

Sheep aged two to seven years old

Note the change in scale at 24 months, at first showing 3 months, then six months age classes (defined under Method). The spread of time over which each stage was observed continued to increase, as expected, but the pattern of gradual increase of stage with age continues.

At two to four years old, the first molar was, with few exceptions, at the mature wear stage of 9A. By 4.5 years, a third were at later stages, and at 5 and 5.5, about half were at later stages. Although 9A was observed even up to 7 years old, from 6 years old more than half of records showed some erasure of the infundibula. This stage, M1 beyond 9A, is used to divide the mandible stage G in the overall summary. Although it is a poor indicator of age in comparison with eruption and early wear stages, the proportion at Gb is greater with increasing age. There were a few cases where M1 was beyond 9A before M3 reached 11G (five, all four years or older; plus nine possible cases: one where M3 was 9/11G and eight where

M3 Years	1¼									2				3				4			5		6		7	
Stage Months	0-14	15	16	17	18	19	20	21	22	24	27	30	33	36	42	48	54	60	66	72	78	84				
nye	567	19	39	**31**	**20**	**20**	**7**	11	8	5	4	1														732
E/J					3	5		**10**	5	8	1															32
1/2A				1		3	4	8	**13**	**24**	15	10	5	2												85
3/4A								2	5	6	**12**	**16**	11	8	1											61
4/5A									1		3	1	4	5	1		1									16
5A									2		3	4	**7**	2	2											20
4A/7A											1	2		1	2		1									7
4A/7G											1			2	3	1										7
5G/6G												1	3	1	2											7
6G											1	3	3	**5**	9	1										22
6G/8G										1		5	5	5	16	2	4		1							39
7/8G												3	2	16	**16**	12	1	1								51
7G/9G													1	1	8	2	3									15
7G/10G													2	1	7	2	3	1								16
9G															3	**8**	2	2	3	1						19
9/10G															1	1	1	1								4
10G														1	3	2	2	1								9
9G/11G													1		5	5	2	3	1							17
10/11G															4	1	**15**	6	3							29
11G															3	5	32	**21**	**43**	**20**	**29**	**6**				159
Total	567	19	39	32	23	28	11	31	34	44	41	46	44	50	86	42	67	36	51	21	29	6				1347

Fig. 6. M3 eruption and wear stages by age class.

Years	1¼									2				3				4			5		6		7	
Stage Months	0-14	15	16	17	18	19	20	21	22	24	27	30	33	36	42	48	54	60	66	72	78	84				
dp4 nye/U/J	24																									24
dp4 in wear	534	18	39	31	23	**26**	**9**	**27**	**20**	20	10	5	3													765
dp4 shed,P4 nye						1		2	1	2	1															7
P4 E/H							1	1	6	**13**	4	4	3													32
U/J									3	7	**9**	7														26
2A									4	3	16	**22**	10	7	1	1	3	2								69
2A/4A									1			3	3		3											10
4A												3		1	1											5
7S											4	5	**12**	**22**	24	4	4									75
8A												1	4	6	**26**	10	5	2	2							56
8A/9A												1	1	1	2	**2**	1									8
5/12W												2	1	3	9	**4**	7	2	1		1					30
9A													2	3	2	**2**	2			1	1					13
12S													3	5	15	16	**42**	**22**	**29**	9	**16**	2				159
13S going																	1	1	3	**5**	2					12
14S																	1	5	10	6	6	1				29
15A																			1	2						3
shed																			2	1	3	2				8
Total	558	18	39	31	23	27	10	30	35	45	44	53	42	48	83	39	66	34	48	24	29	5				1331

Stage 5/12W – anterior infundibulum isolated, posterior part uncertain. (Four records at 4A/7A, 5 at 7S/8A and 4 at 9A/12S are not shown.).

Fig. 7. P4 eruption and wear stages, and grouped dp4 stages, by age class.

M3 was at 10/11G; see later discussion of relative wear and archaeological examples).

For the second molar, the change from 6/7A to 9A occurred during the third and fourth year. At 27 to 33 months the median value was the 'open back' stage 8A (all dentine joins complete except for the posterior lingual fold). By three and 3.5 years, half had reached 9A. By 4 nearly all were at 9A with none at earlier stages at 5 years or more. Only three cases of sheep showing later stages were seen, one each at 6, 6.5 and 7 years (and see note on unaged sheep, below).

The third molar results are complicated by many observations which could only be given to a range of stages, reflecting the practical difficulties of seeing into the back of the jaw. However, a broad picture similar to the earlier-erupting teeth can be seen with increasing stage with age. Note that the number of reversals was greater for the third than for the first and second molars

Incisors Years				**1**												**2**				**3**		**4**		**5**		**6**		**7**		
Stage Months	**0**	**1-10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**24**	**27**	**30**	**33**	**36**	**42**	**48**	**54**	**60**	**66**	**72**	**78**	**84**	
deciduous nye	**6**																											6
di1 present	**6**	**412**	**37**	**4**	**57**	**22**	**13**	4	11	5	3																	574
di1 shed, I1 nye			4							1		1	1															7
I1 E/H/one					6	9	2	1	2	2	4	3	1	2														32
two-tooth						11	5	**35**	**20**	**15**	**21**	**7**	**27**	**18**	**24**	11	8	2										204
I2 E/H/one													1	12	11	6	8	4	1									43
four-tooth													2	3	9	**24**	**27**	**23**	9	9								106
I3 E/H/one															1	6	9	8	4	13	2							43
six tooth															1	1	6	9	**32**	**22**	17	9	4		2			103
six, b.m.																					1	4	2	2				9
I4 E/H/one																		1	4	22	**7**	12		3	1			50
full mouth																	1	1	2	19	16	**36**	**23**	**26**	**13**	**13**	3	153
six/full b.m																					1	2	2	1				6
full, b.m.																					1	6	8	7	8	15	**4**	49
Total	12	412	41	4	63	42	20	40	33	23	28	11	32	35	46	48	59	48	52	85	45	69	39	39	24	28	7	1385

nye – not yet erupted; di – deciduous incisor; I1 E/H/one – one or both first incisors erupting or half up and/or one only at full occlusal height; two-tooth – both permanent first incisors at full occlusal height and unworn, enamel wear or in wear; four-tooth, six-tooth and full mouth similarly for I2's, I3's and I4's; b.m. – broken mouth, i.e., one or more teeth shed (and see text)

Fig. 8. Incisor eruption by age class.

(Fig. 2). Outlying results, i.e. the extreme 2.5% at each end of the ranges, have not been excluded, but undue weight should not be given to them. Even excluding these, the range of stages observed, for example at 42 months, is very large, yet the central two-thirds of results are much less spread, from 6G to 7G/10G.

At twenty-four months, more than half of results were at 1/2A, that is, mandible stage E1/2. At 27 and 30 months, the summer and autumn of the third year, the median value is at 3/4A, with 1/2A still frequent. The posterior cusp of the third molar came into wear during the later part of the third year; by 3 years old, the median value was at 6G and few were still unworn at 3.5. The gradual change from stage 6G to 10G was seen from three to 4.5 years. The mature wear stage, 11G, was reached in two-thirds of cases at five years, and 84% by 5.5.

Replacement of the deciduous fourth premolar with the fourth premolar occurred later than M3 eruption. Compare the double underlined cells and the median values on Figs 6 and 7, and see Fig. 15 in the Appendix, 'Relative Wear', and the discussion of sheep and goats, below. For M3 at E/J, four-fifths retained dp4 and a fifth had dp4 shed or P4 erupting. By the time M3 reached 2A, premolar replacement was under way, with a fifth of P4s in wear. No individual was observed showing attrition on P4 while M3 was still not in wear (Figs 15 and 16 in the Appendix), but there were four cases of E/J in both P4 and M3, and two of P4 at E/H and M3 not yet erupted.

Note that the P4 results included 7.7% reversals (Fig. 2), mostly at the intermediate wear stages. Broadly speaking, 7S was reached during the third year, and the change from 7S to 12S occurred during the fourth and fifth year. The results are of limited usefulness for ageing.

Incisor eruption is shown on Fig. 8. Roughly speaking, four-toothed individuals were in their third year, six-toothed individuals in their fourth, and full-mouths were four years and older. From 27 to 48 months, there was a wide spread of eruption stages seen, but at 27 and 30 months more than half were four-toothed individuals, and at 36 months, more than half were six-toothed. From four years on, loss of incisor teeth – 'broken mouth' – was common, and in some cases it was uncertain whether the corner incisor (I4 or canine), was unerupted or shed, hence the category 'six/full b.m.' The process of eruption and coming into occlusion, 'I1 E/H/one', etc., was more spread in all four permanent incisors than for the cheek teeth.

Twenty-seven sheep without a known year of birth were observed at Butser. The most interesting of these were six Shetlands and one Soay that were already full mouths and with M3 at 11G when first seen. Four of these were seen over a two year period, during which time there was progressive erasure of the M1 infundibula, but only one case of erasure in M2, a Shetland ram reputed to be 9 or 10 years old. No cases of erasure were seen in M3 (mandible stage J) in any sheep.

The age of sheep observed at Payne's mandible stages

The results as a whole are summarized on Fig. 9, grouped as described under Method, with subdivisions of Payne's mandible stages based on the results for the most recently erupted tooth. The columns were standardized, with the sample size shown below. At 12 months only four sheep were seen, and an estimated result was given, using the mean of the 11 and 13 months percentage results. Other irregularities have not been smoothed e.g. at 6 and 7 months, and 16 and 17 months). As before, the cell which includes the median value of each age class is bold and underlined. The cells which include the central two-thirds of results (33% either side of the median) are boxed, and

Year													1										2				3		4		5		6		7			
Month	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	24	27	30	33	36	42	48	54	60	66	72	78	84	No.	
A	**100**	34																																			24	A
B		**66**	**100**	**67**	13	(3)																															88	B
C1/2				33	**76**	**68**	5	10																													80	C1/2
C3/4					11	28	**69**	**79**	22	10																													98	C3/4
C5						(3)	26	8	**44**	28	16																												52	C5
C6+								(3)	31	**62**	**65**	**59**	35	10																									89	C6+
D1/2									(3)		16	31	**37**	**43**	10																								51	D1/2
D3/4											(3)	10	27	43	**69**	**76**	46	**53**	13	8	(9)		(3)																115	D3/4
D5													(3)	5	15	18	**38**	34	**52**	31	36	7	9	(2)	(2)														69	D5
D6+															5	(6)	15	9	35	**50**	**18**	**59**	26	27	7	(2)													77	D6+
E1/2																		(3)		12	36	28	**38**	**55**	37	22	11	4											85	E1/2
E3+																						7	24	14	**51**	**50**	**50**	34	7		3								107	E3+
F5/8																								(2)	(2)	26	36	**60**	**69**	43	10	(3)	(2)						146	F5/8
F9/10																												(2)	10	**31**	13	14	6	(5)					41	F9/10
F/G																											(2)		10	14	**27**	25	8						47	F/G
Ga																													2	5	25	**11**	**36**	19	32	(20)		57	Ga
Gb																													(1)	7	21	47	48	**71**	**64**	**60**		95	Gb
H																																		(5)	(4)	(20)		3	H
Totals	12	35	25	51	38	40	58	39	36	39	37	39	4	61	39	17	39	32	23	26	11	29	34	44	41	46	44	50	86	42	67	36	50	21	28	5	1324	

Stages are defined on Tables 11 to 13. Ga – both M1 and M2 at 9A, M3 at 11G; Gb – M1 beyond 9A, M2 at 9A, M3 at 11G. Ageclasses are defined under Method. For each ageclass column, the median value is bold and underlined; the central two-thirds is boxed; the outlying 2.5% at each end and single outliers even if >2.5% are bracketed. Values for 12 months have been estimated, from the 11 and 13 months percentage results (actual data 2 at D1/2 and 2 at D3/4). Grouped stages have been allotted to adjacent stages, in the proportion of the adjacent stages (38 at C4/5, 20 at C5/7, 44 at D4/5, 7 at E3+/F and 5 at Ga/b). F/G is retained.

Fig. 9. Percentage results for mandible stages by age class.

	A	B	C	D	E	E/F	F	F/G	G	H	
decid nye	6										6
di1 present	18	88	320	129							555
di1 shed, I1 nye			2	5							7
I1 E/H/one				30							30
two-tooth				144	51						195
I2 E/H/one				5	34		2				41
four-tooth				3	67	1	23				94
I3 E/H/one					18	3	15	1			37
six tooth					15	1	65	9	3		93
six, b.m.						1		3	3		7
I4 E/H/one					2		28	6	10		46
full mouth						1	40	23	74	3	141
six/full b.m							1	1	4		6
full, b.m.							3	1	43		47
Total	24	88	322	316	187	7	177	44	137	3	1305

Fig. 10. Incisor eruption in relation to mandible stage.

outliers (the 2.5% at each end of the range, and all outlying single records) are in parentheses. Reading across the table, there is a normal pattern of increasing and decreasing values, with the columnar median in the central parts of the rows. The subdivision of F is interesting, with the central two-thirds of F5/8 at 2.5 to 4 years (146 results), and of F9/10 at 3.5 to 4.5 (41 results), a useful distinction, at the prime of a sheep's life.

The main Payne stages are shown in relation to incisor eruption on Fig. 10.

Breed comparisons

A summary of results by breed and breed group is shown in Figs 11–13 in the Appendix using the subdivided mandible stages. Grouped results, for example C5/7, were allotted to adjacent stages proportionally to the nearest whole number. Each main symbol represents two records. The Scottish Blackfaces are shown on separate columns on Figs 11 and 12, as they span more than one age class. The older ones are included with the rest. They are more tightly aged, e.g. the 54 months age class covers six months (51 months, 1 day – 57 months, 0 days), and the Blackfaces are aged two or three weeks either side of 52.5 months. The Blackfaces have good sample sizes up to 6.5 years. Some older commercial sheep were seen, as CFP did not have many older sheep of traditional breeds (see also Fig. 1). Note, when reading the tables, the greater reliability of data in the columns than in the rows (see Method). To save space, the Shetlands, White-faced Woodlands, Hebrideans, Manx Loghtans, Jacobs and others, from both CFP and Butser, were combined to an 'Other minority' group. There is variation within these, but they are all traditional or rare breeds which have not been bred with improved breeds in the recent past (at least the last 60 years, E. Henson, pers. comm.). (For simplicity they are referred to as a breed not a breed group, below).

The important question is whether there are large differences in the results from different breeds and farms. There has long been an uncertainty about whether animal breeding in the last two hundred years has caused an acceleration in eruption timing, as some studies have suggested (see Deniz and Payne 1979, Table 6), although other work suggests this has been exaggerated. Bull and Payne (1982, 65) discuss Brown's 1902 edition of his book on the dentition of farm animals in which Brown comments that no change in the rate of development of the teeth of cattle, sheep or swine had been seen in the 50 years since the 1860 first edition (and see Payne 1984, and Legge and Dorrington 1985, 130–131).

Fig. 11 shows the first year results. Overall, the general similarity of the pattern for all sheep is noted. At eight of the 12 age classes, the mode (highest value) for each breed was at the same mandible stage. The Scottish Blackfaces confirm the similarity, from a different breed and geographical area. At 4.5 months, most are at C1/2, as are the other breeds at 4 and 5 months, with a few at C3/4, as would be expected from the 5 months results. At 10–11 months, results were intermediate between the minorities at 10 months and 13 months. At 16–17 months and 22–23 months (Fig. 12), and at later ages (Fig. 13), they show a pattern similar to the minorities. At all these points, the Blackfaces show a narrower spread of stages than the records as a whole.

The Soays and Mouflons, as the most primitive of the breeds seen, may be expected to be rather different (Clutton-Brock *et al.* 1990). Yet for nearly all age classes, the mode for the Soays is at the same stage as the results overall. There is, however, a regular tendency for some Soays to be at earlier stages, and none at later stages of each age class. As each molar tooth erupts, most Soays are the same as the minorities, but there are a few not reaching the early-wear stage, at the age where all other breeds have reached C1/2, D1/2 or E1/2 respectively, see, for example, the Soays still at B at 4 and 5 months (five individuals), or still at D5 or D6+ at 24 to 30 months. Note the similarity in the results, though, at 9 and 10 months, and 3.5 to 6.5 years.

Three Mouflons were examined, two ewes (9 and 12 records) and a ram (3 records), and a Mouflon cross Soay (6 records; aged 3 to 15 months, i.e. the records later than 15 months are all Mouflon). The Mouflon records were mostly at the mode for Soays, sometimes at one stage earlier, but almost always within the range of Soays examined. An example is the Mouflon and a Mouflon x Soay with M2 not yet in wear at 13 months. (The Mouflon record at D3/4 at 22 months is probably an error, as this sheep was at E1/2 at 24 and 27 months).

At 6 and 7 months, there is a difference within the Soay results with four records at C5 at 6 months, and only one at 7 months, which was a result of missing a six months visit one year and a seven months visit the next: an example of variation due to season or management within one farm and breed.

A few commercial sheep were seen. The few younger

sheep examined included eight at 3 months, none of which showed wear on M1, though all had M1 erupting (anterior element erupting or half-up and posterior element unerupted). Other records were also within the range seen overall but tending towards the later stages at each age class, excepting for the three cases at stage H, M2 beyond 9A.

The first case of wear on M3 was in three minorities, a Butser Manx Loghtan ram, a CFP Shetland ram, and a CFP White-faced Woodland ewe, at 19 months, and four commercial ewes at 20 months, with an increasing proportion of minorities with M3 in wear at 21 and 22 months. No Soays showed wear on M3 until 24 months, when 8 of 14 (57%) were in wear compared to 77% of 31 Blackfaces at 22/23 months. At 27 and 30 months, five Soay records (three individuals) were the only sheep with M3 still not in wear.

Looking at the older sheep (27 months to 7 years), in eight of the 12 age classes the mode for the minorities, Blackfaces and Soays were at the same mandible stage. The Soays, again, have a higher proportion at earlier stages, but most are at F/G or G by 4.5, as are the Blackfaces. By 5.5 almost all Soays had reached G. The older commercial sheep examined at 5.5 to 6.5 were almost all at G, with one case each at 6 and 6.5, plus the single record at 7 years, at stage H. The four minority breed records (four individuals) at 7 years were still at stage G (one at Ga and three at Gb).

Sex differences

No difference was seen between ewe and ram lambs in the age at which C1/2 and C3/4 was seen. Only at Butser were any older rams seen. Of 51 individuals at stage D and beyond, 14 were rams, and 37 ewes. The earliest record of D1/2 was in two ewes, at 11 months (a Hebridean and a Shetland). The earliest five records of D3/4 were a Soay ewe at 10 months and four rams at 11 and 12 months (four different individuals, a Shetland, Hebridean, Soay and Manx Loghtan). One of these four rams, the Manx Loghtan, was the earliest record of E1/2, at 19 months. The range of stages seen at 13 and 24 months is shown on Fig. 14. Numbers are not large enough to be very useful.

Relative wear

The wear on earlier erupting teeth in relation to later erupting teeth has been used in ageing studies (e.g. Grant 1978, Grant 1982 especially Table 3, Deniz and Payne 1982, 193–196, and, for humans, Miles 1963, 2001) and may be used to study wear-rate, and to study sheep/goat differences (see below). The wear of one tooth in relation to earlier erupting teeth are shown on Fig. 15. Taking the row or column of one stage of the later erupting tooth, the stages seen in the earlier tooth can be read. The median is bold and highlighted. In archaeological samples the rate of wear can be recorded as slower, similar, faster, or much faster than that seen here. For example, each mandible may be recorded as less than, equal, beyond or well beyond the median value, or even outside the range (see discussion of the Makrigialos sample, below). If the wear-rate appears fast in younger mandibles, this will be useful in judging whether very worn older jaws are the result of wear or age (but see also Sheep/goats). High wear rate is likely to be the result of high soil ingestion (Nolan and Black 1970, Healy and Ludwig 1965), and this may allow inferences to be made about stocking rate, pasture shortage, or pasturing on arable land, for example, sheep-folding on fallow.

The wear-rate figure may be useful in estimating stage in incomplete archaeological mandibles.

Sheep/goat differences

The striking difference observed between sheep and goats is in the wear rate of dp4 and the timing of eruption of P4. The deciduous premolar is lower crowned in goats (see Fig. 3, Payne 1985) and therefore erasure of the infundibula and replacement by the permanent tooth occurs sooner. Both Habermehl (1975) and Silver (1969) gave earlier P4 replacement times for goats than sheep. In Deniz and Payne's study of goats, stage 16L was reached in half of the records at six months (Deniz and Payne 1982, Fig. 20), whereas in the sheep studied here, this did not occur until 15 to 20 months. 14L was a much more frequent record than 16L in sheep (305 records of 14L and15K, and 97 of 16L), which was the reverse in goats (58 at 14L, 182 at 16L), i.e., in goats the anterior infundibulum was beginning to erase soon after all dentine joins were complete. Eruption of M3 and P4 in the sheep is described above and relative stages are shown on Fig. 15. In goats, the approximate average eruption of M3 was 25 months and for sheep it was 21 months, while for P4 eruption the figures are a nearly exact reversal (Fig. 16), that is, in goats it is the permanent premolars which erupt during the second winter, whereas in sheep, it is the third molar. It may well be important for goats to have functioning premolars when the spring browse appears. Relative eruption of M3 and P4 at stages E/J and 1/2A, and probably also at 3/4A, look to be useful indicators for separating sheep and goats, in addition to the work done on young lambs and kids (Payne 1985) and permanent premolars and molars (Halstead *et al.* 2002).

Differences in the ease of use of the speculum was referred to in the 'Accuracy' section above. Goats, being browsers, open their mouths wider. As an aside to this point, the morphology of the mandibular condyle in sheep and goats may reflect this difference. The posterior facet at the lingual corner of the condyle is usually larger in goats.

Of the morphological differences between lambs and kids observed by Payne, the shape of the metaconid of

dp3 and the ridge arising from it was the character most easily seen in live sheep (Payne 1985, Fig. 2: 3b). Observations of twenty 4.5 months old Blackfaces confirms the description given for lambs, with the ridge connecting to the posterior part of the tooth.

Discussion

In drawing conclusions from the results, the difficulties and inaccuracies described should be kept in mind. However, the correlation of mandible stage with age class in Fig. 9 is strong. For single breeds, the Scottish Blackfaces alone or the Soays alone, the range of stages seen at each age was narrower than overall, and this is also likely to be true of archaeological samples.

Using Payne's A, B, C…J stages, in general terms, stage A records were lambs a few days or weeks old, stage B were one to three months, stage C three/four to 12 months, stage D were yearlings and stage E was reached at the end of the second year. Excluding single outliers, during the first two years there are eleven months in which all sheep examined were of a single stage: stage B at two months, stage C at five to nine months and stage D at 14 to 18 months.

Eruption of the first molar at three months is confirmed, with wear beginning at 3 and 4 months. This figure is quoted by most authors, and was similar for goats (Deniz and Payne 1979, 1982). Second molar eruption is given as 9–12 months by some authors (Silver 1969 and Sisson & Grossman 1953, quoted in Deniz and Payne 1979, Table 6), which matches well the results presented here with initial wear at 10–13 months, and was similar for goats. Several authors give 9 months (e.g. Habermehl 1975, Miller and Robertson 1959). This is correct for 'first signs of eruption': at 9 months less than half were erupted, and at 10 months more than half were erupted. Third molar eruption was widely spread at 18 to 27 months, which is similar to 18 to 24 months given by Silver and Sisson & Grossman. Other authors give 18 months, and as with M2, this would be true for the first signs of eruption in some sheep. The 1790 'semi-wild hill sheep' figure of Silver's is not close to results here for any of the three molar teeth (unless eruption was taken to mean 'in occlusion on all cusps', 4A for M1 and M2 or 6G on M3, in which case they are close for M1, late for M2 and comparable for M3). There is confirmation, therefore, of the quality of 19th century research, and of Brown's 1913 observation.

The mandible stages could be labeled as shown in Fig. 17 for use in histograms and survivorship curves (e.g. Dobney *et al.* 1996, Fig. 52a–e). Subdivision of the histogram bar, as described above ('Mandible stages'), would preserve the general pattern, which would be obscured by using a bar for each subdivision if sample sizes are not large; it would also show some primary data. The survivorship curve could use the subdivided stages without loss of clarity. If points are labeled with the 'central point', it should be made clear that the stages overlap, and the 'majority' or 'all records (except outliers)' figures quoted. The points are neither a linear nor a logarithmic scale, but they do show detail at the points of greatest interest. It would aid clarity if, for example, the 3, 6, 12, 24 months, 3 and 4 year points could be shown on the outer part of the frame of the figure.

The probable age of archaeological mandibles could be calculated from the figures in Fig. 9 (Chamberlain, pers. comm., Buck *et al.* 1996, Chamberlain 2000). Taking the row at mandible stage C3/4 as an example, the percentage values, at 4 to 9 months, summed and normalized, give probabilities of 0.050, 0.128, 0.315, 0.361, 0.100 and 0.046 for the six age classes. If the assumption is made that all ages are equally likely (the 'uniform prior'), the ten mandibles at stage C3/4 might be allotted to the six ages classes thus: 0.5, 1.28, 3.15, 3.61, 1 and 0.46, or, to the nearest whole sheep: 1, 1, 3, 4, 1 and 0. If this method is applied to whole mandible samples, some smoothing of irregularities in the data may be advised, and the correct probability value needs to be applied at the three-months and six-months age classes; (e.g. to keep the 'uniform prior', the series at stage E3+ is: 7, 24, (14x3), …(34x6)…). Estimated values would be needed for mandibles showing stage A, which may include pre-natal deaths, and the later stages, G, H and J. In estimating values for the late stages, assumptions have to be made about likely survivorship, and a 'model prior' may be necessary (an old sheep is more likely to be nine than 13 years).

A meaningful, yet space-efficient, way of showing primary tooth wear stages in archive tables, is to make a table comparable with Grant's Table 3 (Grant 1982), but with the major stages as the columns, A+B, C, D, etc., and the tooth stage combinations, ordered, in each column. Payne's stages are sometimes abbreviated by removing the suffix, '2' instead of '2A', which for most teeth means only a small loss of information; but for M3 the suffix is needed, to show whether the posterior cusp is in wear.

Seasonality

The spread of ages for each stage during the first year is small enough to be useful in studies of season of death in archaeological samples, with some helpful information for the second year.

Lambing time for sheep seen is given above ('Tagging and date of birth'). Lambing is later within the UK as latitude and altitude increases. Hafez (1969) quotes later February and March for southern British sheep, but this is earlier than in the sheep examined here, and the St. Kilda Soays. Lambing normally occurs over about a five week period. If a presumption is made that lambing occurs from 1st to 30th April, during July lambs would be aged

2 months, 0 days to 4 months, 0 days, i.e. half would be age class 3 months, and a quarter would be in each of age classes 2 and 4. Or put the other way, the 3 month age class (2 months, 16 days to 3 months, 15 days) would occur from mid June to mid August. The six months class would occur from mid September to mid November, and the nine months class from mid-December to mid-February. Deaths during February would show the stages seen at ten months (50%) and nine and eleven months (25% each).

Taking this presumed lambing time and the central two-thirds of results on Fig. 9, mandibles at C1/2, three to five months of age, are in the summer of their first year, and those at C3/4, five to eight months, are in the autumn or early winter. C5, six to nine months, are autumn or winter, and C6+, eight to twelve months, late autumn to spring (defining summer as June to August, autumn as September to November, winter as December to February and spring as March to May). Early wear on M2, D1/2, at 10 to 13 months, would be seen in winter and spring, and could be winter losses or yearling spring lamb. Estimates can be suggested for stages D3/4 to E1/2, but with a wider range. A more detailed presentation of the ranges could be given by using probabilities, as referred to above. Where there are young lambs, use of Figs 1 and 2 will allow finer ageing, from early wear stages of dp4, and eruption of M1. Mandible stage B could be divided into 'Ba', 'dp4 in wear, M1 unerupted', two months or less, and Bej, 'dp4 in wear, M1 erupting', probably 3 months old (Fig. 2)(erupting, for live sheep, is a little more advanced than Ewbank *et al.*'s E).

Comparative sources

Payne's 1973 estimates for the mandible stages are shown on Fig. 17 as they have been widely quoted, even long after the goat study was published. In broad terms, the estimates were good. The main adjustments indicated are the earlier beginning to stage C, the considerable overlap of stages, and the higher upper limits of stages E, F and G. The Turkish Angora goats, shown in the final column of Fig. 17, were very similar to the study sheep up to the beginning of stage G. The goats were about a month later at the C to D transition, and as shown above, somewhat later at the D to E transition. Goats reached the latest mandible stages earlier than the sheep.

In the sheep, few cases of late wear were seen in M2 and none in M3, stages H and J, primarily because so few old sheep were seen. There is some information about older sheep from other studies, see Fig. 18. In the St. Kilda Soays (Clutton-Brock *et al.* 1990) and the Shetland sheep studied by Davis (1996 and 2000), the first cases of Stage H were, as in the present study, at six years of age. Some earlier cases were found in Moran and O'Connor's study of sheep in museum collections (1994, and pers. comm.). Cases of Stage J, where M3 is wearing to the base, were not seen in the St. Kilda Soays nor in the study sheep. One of the Shetland six-year olds was at Stage J, as were several eight and nine-year olds in the museum study.

Further study of older sheep is needed, both in tooth wear stages seen in known-age older sheep, and in estimating the upper limit used for stages H and J on Fig. 17. The age of the live population of registered Rare Breed sheep in January 2003 is shown on Fig. 20, (E. Henson, Grassroots System, pers. comm.), a very large and interesting data-set from the Rare Breeds Survival Trust. For these sheep, the normal life-span is up to nine or ten years, though numbers reduce somewhat at six to eight years. The nine and ten year olds will be described by the farmers as 'old'. Sheep of 11 to 13 are few, and over 13 rare, with the oldest nearly 19 – all may be described as very old. Some aspects of the age structure of these sheep may be typical of sheep generally, e.g. that few live beyond ten. Other aspects are probably not typical, for example in the keeping of ewes so long, which maximizes the progeny from each sheep, and contributes to the survival of the breed. The very old sheep will certainly include some that have become pets. On modern hill farms in the UK, sheep over 7 years old are unusual, but lowland farms often keep their best ewes a year or more longer, if still with good teeth and udders and still producing twins and triplets (Griffith, pers. comm.).

Of the mandibles from St. Kilda (Clutton-Brock *et al.* 1990), all the records were within the range seen in the present study, except for one M3 at 10H at 11 years.

The mandible stages of the Shetland sheep studied by Davis (1996, 2000) were compared with the study results (Fig. 9). They were within the range of stages seen, except for one at 15 months with M2 only just in wear. For those up to three years old (all rams and castrates), most were at the stage which includes the median value, with some cases one stage earlier or later and only one two stages later (seven one stage earlier, 20 equal to, six one stage later, and the one two stages later). Those over three years (8 wethers and 26 ewes) tended to be one stage later (two one stage earlier, six equal to, 17 one stage later, and one two stages later). More of the Shetlands had reached Gb, where M1 is beyond 9A, at 4.5 years (55 months) than in the study sheep, and more had reached stage H at nearly 7 years (79 months).

In Moran and O'Connor's study, all the results for dp4 and P4 quoted are within the ranges seen. For M1, all are within the range except the 44 months old Gotland castrate at 15A. For M2, most records are within the range, but 8A/B was not normally reached by 18 months, and the M2 at 15A at 72 months is earlier than seen in this study. The description of results for M3 show a few cases outside the range seen here, viz. the 36 months old Soay with M3 erupting and not yet in wear; C51 with M3 at 11G at 32 months and the Soay castrate (82:574) at 11G at 36 months: both very early; and, as suggested, WM30 was probably wrongly aged.

Payne's sample of modern Turkish sheep, all

slaughtered in February 1972 (1973, Fig. 14), included five estimated to be 9–12 months and three 21–24 months. These all look correctly estimated. Of the older sheep, one, 'KAR 1', could be rising 2 or rising 3. The others were all at stages G, H or J, half of them beyond G, which is in contrast to the results here, see Fig. 19.

Grant's tooth and mandible wear stages

Grant's tooth wear stages (1975, 1982) are similar to Payne's. The work here suggests that it is worth adding a stage between 'b' (equivalent to '2A') and 'c' (equivalent to 5A) so that stage 4A is recorded separately, i.e. four cusps in wear (six for dp4) with dentine not continuous anteriorly. Grant's stage 'h' needs to be used with caution, making it clear whether the stage seen implies that the infundibulum is nearly worn to the base, or whether the infundibulum is just of an unusual shape. In Fig. 19, this latter interpretation is made, and 'h' is included within Payne stage 9A. Because in live sheep one cannot see the earliest stages before the tooth is visible in the mouth, the mandible wear stage (MWS) could not be calculated until all three molar teeth were visible. The MWS could be calculated for 567 records, although this required giving a single figure for grouped values (e.g. 11.5 for 8A/9A). Median values were MWS 29 at 24 months, 31 at 30 months, 33 at 3 years, 34 at 4 years, 38 at 5 years and 39 at 6 years. Because the eruption and early wear stages are less variable than late wear stages (see Figs 3 to 6) and tooth wear stage 'g' is so long-lasting, it was considered more sound to base stages on the most recently-erupted tooth where possible. The detailed presentation of results (Grant 1982, Table 3) is very valuable, and it is recommended that individual mandible results should be published.

Some archaeological examples

A detailed study of archaeological samples is beyond the scope of this study, but an example of the use of the results is taken by looking at older sheep. Age estimates for late stages need to use information about relative wear rates, and assumptions about likely survivorship. Payne's modern Turkish sheep sample and the archaeological sample from Asvan Kale both included about equal numbers at stage G and stage 'H plus J', see Fig. 19. The same is so for the much larger sample of sheep from late Neolithic Makrigialos, Greece (Halstead, pers. comm.). At the UK archaeological sites (summarized by Grant 1982, Table 3), however, a much lower proportion were at H or J, and the same was so for medieval sheep from Lincoln (Dobney *et al.*1996) (Fig. 19). Are the Turkish and Greek sheep older, or are their teeth wearing down faster, and reaching H and J sooner?

The use of the Relative Wear table (Fig. 15) is useful in considering this question. For the sheep from Makrigialos, a cross-tabulation of dp4 and M1 shows that at every wear stage of M1 (not shown, sample size 132), the mode stage for dp4 is at a later wear stage than the mode for the study sheep. Taking eruption as being less variable than wear, it can be suggested that wear-rate is faster for the Greek sheep. Somewhat earlier age estimates may therefore be suggested for the mandible stages which depend on wear. Consideration could be given to using C5+ and Cej as the final two subdivisions of C (see 'Mandible stages', above). The comparable dp4 by M1 cross-tabulation for goats confirms the faster wear of goat deciduous teeth, with all cases beyond the mode, and more than half (9 of 16) beyond the range seen in the study sheep. A further line of enquiry is to compare the number of cases of M1 worn beyond 9A before M3 has reached 11G. In the Makrigialos sheep, M1 was usually already beyond 9A before M3 reached the mature-wear stage, and consequently there were few records in the stage Ga (Fig. 19). This is in great contrast to the study sheep, and usefully indicates faster wear rather than older sheep in the Greek sheep sample reflecting the drier climate in Greece, and the greater soil ingestion (for references see 'Relative wear' above).

Returning briefly to Grant's UK material, this last comparison shows an intermediate position, with M1 relatively more worn than the study sheep, but less worn than the Greek sheep.

Aspects for further study

A number of aspects of the sheep data have not been presented, for example the wear stages of incisor teeth, the detailed tooth stages for dp4, dental anomalies, the differences between breeds for incisors, and differences within the minority breeds and between the Scottish Blackface farms. The study lacked good data for rams and castrates, and older sheep. A more detailed comparison of the sheep and the Turkish Angora goats would be of interest. There may be variation in tooth size and shape, for example, in the depth of the folds on which the intermediate wear stages are based, and the depth of the infundibula.

Conclusions

In conclusion, the study suggests that age estimates for tooth eruption in archaeological material may be made with considerably more confidence than has been the case previously. The 19th century data, on which we have relied rather tentatively in the past, have proved reliable. The amount of variation is quantified, and methods of analysis need to bear this variation in mind. The sub-divided mandible stages used for the overall summaries in Figs 9 and 17 are valuable. Of these stages, those which depend on early wear of the latest-erupted tooth provide information almost as reliable as for eruption, and these include many of the stages up to

three years old. Tooth eruption in goats is very similar, but with the difference in the order of eruption of P4 and M3.

Mandible stages which depend on later-wear of individual teeth are in a different category, as the age of reaching these stages depends on how fast the teeth wear. Study of relative-wear suggests that the teeth of the study sheep, kept mostly on permanent pasture, wear more slowly than UK Romano-British to medieval sheep, and considerably more slowly than Neolithic Greek sheep. Age estimates may therefore be adjusted, on an informed basis.

Acknowledgements

Grateful acknowledgement is made to Sebastian Payne for practical help and later discussion; to Joe Henson at the Cotswold Farm Park, the late Peter Reynolds at Butser Ancient Farm and John Spence at the Animal Diseases Research Association, The Moredun Institute; and their staff, especially Robert Boodle and Alex Wyman; to numerous sheep helpers, in particular, Andrew King, Martin Morris, Sheila Raven and John Giorgi; to the British Academy and the Robert Kiln Trust for funding part of the practical work; to Bob Wilson, Bruce Levitan, Andrew Speedy, Barry Cunliffe, Sunny Dawson, Keith Dobney, Paul Halstead, Andrew Chamberlain, Simon Dobson, Terry O'Connor, Simon Davis, Peta Sadler, Judy Griffith, Elizabeth Henson and Andrew Millard for discussion and help on various aspects of the work; to Derilyn Frusher for typing records into the database while a student at Sheffield University, to the Rare Breeds Survival Trust for the information about the age of live sheep, and to Paul Halstead for information from Makrigialos.

References

Bourdillon, J. and Coy, J. 1980. The Animal Bones, in Holdsworth, P. (ed.), *Excavations at Melbourne Street, Southampton, 1971–76*. CBA Research Report **33**, 79–121.

Brown, G. T. 1860. *Dentition as Indicative of the Age of Animals of the Farm* (edns. of 1902, 1913). London: Murray.

Buck, C. E., Cavanagh, W. G. and Litton, C. D. 1996. *Bayesian Approach to Interpreting Archaeological Data*. Chichester: Wiley.

Bull, G. and Payne, S. 1982. Tooth eruption and epiphysial fusion in pigs and wild boar, pp. 55–71, in Wilson, R., *et al*. (eds) *Ageing and Sexing Animal Bones from Archaeological Sites*. Oxford: British Archaeological Reports, British Series **109.**

Bullock, D. and Rackham, J. 1982. Epiphysial fusion and tooth eruption of feral goats from Moffatdale, Dumfries and Galloway, Scotland, pp. 73–80, in Wilson, R. *et al*. (eds) *Ageing and Sexing Animal Bones from Archaeological Sites*. Oxford: British Archaeological Reports, British Series **109.**

Chamberlain, A. T. 2000. Problems and prospects in palaeodemography, pp. 101–115, in Cox, M. and Mays, S., *Human Osteology in Archaeology and Forensic Science*. London: Greenwich Medical Media.

Clutton-Brock, J., Dennis-Bryan K., Armitage, P. L. and Jewell, P. A. 1990. Osteology of the Soay Sheep. *Bulletin of the British Museum Natural History (Zoology)* **56**, 1–56.

Davis, S. J. M. 1987. *The Archaeology of Animals*. London: Batsford.

Davis, S. J. M. 1996. Measurements of a group of adult female Shetland sheep skeletons from a single flock: a baseline for zooarchaeologists. *Journal of Archaeological Science* **23**, 593–612.

Davis, S. M. J. 2000. The effect of castration and age on the development of the Shetland sheep skeleton and a metric comparison between bones of males, females and castrates. *Journal of Archaeological Science* **27**, 373–390.

Deniz, E. and Payne, S. 1979. Eruption and wear in the mandibular dentition of Turkish Angora goats in relation to ageing sheep/goat mandibles from archaeological sites. *Archaeozoology* **1**, 153–163, Kubasiewicz, M. (ed.), Agricultural Academy, Szczecin, Poland.

Deniz, E. and Payne, S. 1982. Eruption and Wear in the mandibular dentition as a guide to ageing Turkish Angora Goats, pp. 155–205, in Wilson, R. *et al.* (eds) *Ageing and Sexing Animal Bones from Archaeological Sites*. Oxford: British Archaeological Reports, British Series **109.**

Dobney, K. M., Jaques, S. D. and Irving, B. G. 1996. *Of Butchers and Breeds*. Lincoln Archaeological Studies No. **5**.

Ewbank, J. M., Phillipson, D. W. and Whitehouse, R. D. 1964. Sheep in the Iron Age: a method of study. *Proceedings of the Prehistoric Society* **30**, 423–426.

Grant, A. 1975. The Animal Bones, pp. 262–287 in Cunliffe, B., *Excavations at Portchester Castle, I*. Society of Antiquaries of London **33**.

Grant, A. 1978. Variation in dental attrition in mammals and its relevance to age estimation, in Brothwell, D. K. and Thomas, K. D. (eds) *Research Problems in Zooarchaeology*. London: Institute of Archaeology Occasional Paper No.**3**.

Grant, A. 1982. The Use of Tooth Wear as a Guide to the Age of Domestic Ungulates, pp. 91–108, in Wilson, R. *et al*. (eds) *Ageing and Sexing Animal Bones from Archaeological Sites*. Oxford: British Archaeological Reports, British Series **109.**

Habermehl, K. H. 1975. *Die Alterbestimmung bei Haustieren, Pelztieren un beim jagdbaren Wildtieren*. Berlin: Paul Parey.

Hafez, E. S. E. (ed.). 1969. *The Behaviour of Domestic Animals*, 2nd ed. London: Bailliere, Tindall & Cassell.

Halstead, P., Collins, P. and Isaakidou, V. 2002. Sorting the sheep from the goats: morphological distinctions between the mandibles and mandibular teeth of adult *Ovis* and *Capra*. *Journal of Archaeological Science* **29**, 545–553.

Healy, W. B. and Ludwig, T. G. 1965. Wear on sheep's teeth. I. The role of ingested soil. *New Zealand Journal of Agricultural Research* **8**, 737–752.

Higham, C. F. W. 1967. Stock rearing as a cultural factor in prehistoric Europe. *Proceedings of the Prehistoric Society* **33**, 84–106.

Hillson, S. 1986. *Teeth*. Cambridge University Press.

Jewell, P. A., Milner, C. and Morton-Boyd, J. 1974. *Island survivors – the Ecology of the Soay Sheep of St. Kilda*. University of London.

Legge, A. J. and Dorrington, E. J. 1985. The animal bones, pp. 122–33 in France, N. E. and Gobels, B. M. (eds) *The Romano-British temple at Harlow, Essex*. West Essex Archaeological Group.

Levitan, B. 1982. Errors in recording tooth wear in ovicaprid mandibles at different speeds, pp. 207–215, in Wilson, R. *et al.* (eds) *Ageing and Sexing Animal Bones from Archaeological Sites*. Oxford: British Archaeological Reports, British Series **109.**

Miles, A. E. W. 1963. The dentition in the assessment of individual age in skeletal material, pp. 191–209, in Brothwell, D. R. (ed.) *Dental Anthropology*. London.

Miles, A. E. W. 2001. Miles' method of assessing age from tooth wear revisited. *Journal of Archaeological Science* **28**, 973–983.

Miller, W. C. and Robertson, E. D. S. 1959. *Practical Animal*

Husbandry. Edinburgh and London: Oliver & Boyd.
Moran, N. C. and O'Connor, T. P. 1994. Age attribution in domestic sheep by skeletal and dental maturation: a pilot study of available sources. *International Journal of Osteoarchaeology* **4**, 267–285.
Noddle, B. 1974. Ages of epiphyseal closure in feral and domestic goats and ages of dental eruption. *Journal of Archaeological Science* **1**, 195–204.
Nolan, T. and Black, W. J. M. 1970. Effect of stocking rate on tooth wear in ewes. *Irish Journal of Agricultural Research* **9**, 187–196.
O'Connor, T. P. 1991. *Bones from 46-54 Fishergate*. London: The Council for British Archaeology, The Archaeology of York **15/4**.
Payne, S. 1973. Kill off patterns in sheep and goats: the mandibles from Asvan Kale. *Anatolian Studies* **23**, 281–303.
Payne, S. 1984. The use of early 19th century data in ageing cattle mandibles from archaeological sites, and the relationship between the eruption of M3 and P4. *Circaea*, **2**, 77–82.
Payne, S. 1985. Morphological distinctions between the mandibular teeth of young sheep, *Ovis*, and young goats, *Capra*. *Journal of Archaeological Science* **12**, 139–147.
Payne, S. 1987. Reference codes for wear states in the mandibular cheek teeth of sheep and goats. *Journal of Archaeological Science* **14**, 609–614.
Silver, I. A. 1969. The ageing of domestic animals, pp. 283–302 in Brothwell, D. R. and Higgs E. S. (eds) *Science in Archaeology*. London: Thames and Hudson.
Simonds, J. B. 1854. *The Age of the Ox, Sheep and Pig*. London: Orr & Co.
Sisson, S. and Grossman, J. D. 1953. *The Anatomy of the Domestic Animals*. Philadelphia: W. B. Saunders Company.
Weinreb, M. M. and Sharav, D. M. D. 1964. Tooth development in sheep. *American Journal of Veterinary Research* **107**, 891–906.
Wilson, R., Grigson, C. and Payne, S. 1982. *Ageing and Sexing Animal Bones from Archaeological Sites*. Oxford: British Archaeological Reports, British Series **109**.

Gillian G. Jones
Church Farm Garth
Shadwell
Leeds
LS17 8HD

Appendix

Stage		Ageclass/ Breed	0	1	2	3	4	4½ Sc. Bl.	5	6	7	8	9	10	10¾ Sc. Bl.	11
A	dp4 not yet in wear	Soay Other min. Sc. Blackf.	● ■• ♦♦♦	●●●● ■												
B	dp4 in wear, M1 not yet in wear	Soay Moufl, MxS Other min. CFP cross		●●●●● ● ■■■■■•	●●●●● ●●● • ■■•	●●●●● ● • ■■■■■ ■ ✞✞✞	●●•		•								
C1/2	M1 anterior cusp(s) only in wear	Soay. Moufl, MxS Other min.				●● ■■■■■ ■•	●●●●● ●• ■■■■	 ♦♦♦♦♦ ♦♦♦•	●●●●● ●●• • •	●•	●●					
C3/4	M1 at 3/4A, M2 not yet in wear	Soay Moufl, MxS Other min. CFP cross					•	 ♦•	●• • ■■■	●●●●●• ■■■■■ ■■■■■ ■■ ✞✞•	●●●●● ●● • ■■■■■ ■• ✞	●●• • ✞	 ✞			
C5	M1 at 5A, M2 not yet in wear	Soay Moufl, MxS Other min. CFP cross							 •	●● ■■■■• •	• ■	●• • ■■■■■• ✞	●• ■■■ ✞	• ■■■		
C6+	M1 at 6A or more, M2 not yet in wear	Soay Moufl, MxS Other min. CFP cross									• 	●• ■■ ✞✞	●●●●●• • ■■■■• ✞•	●●●●● ○ ■■■•	♦♦♦♦♦ ♦	●●●●●• • •
D1/2	M2 anterior cusp(s) only in wear	Soay Other min. CFP cross										 •		■■•	♦♦♦♦♦•	■
D3/4	M2 at 3 or 4A M3 not in wr	Soay Other min.												•	•	■•

Each main symbol represent two records. ● Butser Soays, ○ Mouflon or Mouflon cross Soay, ■ Other minority breeds, ◆ Scottish Blackfaces and ✞ Cotswold Farm Park (CFP) commercial crossbreds; • represents one record, e.g., ●●●• represents seven Soay records. Soay cross Suffolks are not shown. Records at grouped stages, C4/5, C5/7, D4/5, E3+/F and F7/10, were allocated in the proportion of the adjacent stages, to the nearest whole number. Scottish Blackfaces are given their own column for the first and second years.

Fig. 11. Mandible stages by breed, age classes 0 to 11 months, each main symbol representing two records.

Stage		Ageclass/ Breed	12	13	14	15	16	16½ Sc. Bl.	17	18	19	20	21	22	22¾ Sc. Bl.	24
C6+	M1 at 6A plus M2 unworn	Soay Moufl, MxS		●● ○												
D1/2	M2 anterior cusp(s) only in wear	Soay Other min. CFP cross	• •	●●● ■■■■■ ■■■■• •	● • •											
D3/4	M2 at 3/4A M3 not yet in wear	Soay Moufl, MxS Other min. CFP cross	• •	● • ■■■■■ ■■■■■ ■	●●● ■■■■■ ■■■■• ✞	●●• • ■• ✞•	● ■■■■	♦♦♦♦♦ ♦♦♦	●● • ■ •	●•	• •	•		•		
D5	M2 at 5A, M3 not yet in wear	Soay Moufl, MxS Other min. CFP cross		 ■•	 ■ ✞✞	 ✞✞	● ■■■ ✞✞✞	 ♦♦	●●• ■• ✞•	●●• ■■• ✞	●●• ■■	●●	• •	●• •		●
D6+	M2 at 6A or more, M3 not yet in wear	Soay Moufl, MxS Other min. CFP cross			 • •	 •	 ■■ ✞		• •	●• ■• ✞	● ■■■■■	• •	●●● ■■■■■•	●● ■	 ♦♦♦•	●• • •
E1/2	M3 anterior cusp(s) only in wear	Soay Moufl, MxS Other min. CFP cross									■•	 ✞✞	■■■■	■■■■■•	♦♦♦♦♦ ♦♦♦♦	●●● • •
E3+	M3 central cusp(s) in wr, distal unworn	Soay Other min. CFP cross											■	■■■•	♦♦•	●
F5/8	M3 5G to 8G														•	

Each main symbol represents two records.

Fig. 12. Mandible stages by breed, age classes 12 to 24 months.

Stage		Ageclass/ Breed	27 mo	30	33	3 yr 36	42	4 yr 48	54	5 yr 60	66	6 yr 72	78	7 yr 84
D5		Soay	•											
D6+		Soay	●•	•										
E1/2	M3 anterior cusp(s) only in wear	Soay Moufl, MxS Other min. Sc. Blackf CFP cross	●●●• • ■■ ♦ •	●● ■• ♦• 	●● • 	• • 								
E3+	M3 central cusp(s) in wear, distal cusp unworn	Soay Other min. Sc. Blackf CFP cross	●● ■■■■• ♦♦♦ ✞	●●●• ■■■■■• ♦♦• 	●●●●● ■■■■■ ■ 	●●●• ■■ ♦♦• 	●• • ♦ 		■					
F5/8	M3 distal cusp in wear, 5G to 8G	Soay Moufl, MxS Other min. Sc. Blackf CFP cross	 • 	● ■■■■• •	● ■■■■■ ■■ 	●●• ■■■■ ♦♦♦♦♦ ♦♦♦♦	●●●●● ●●●• ■■■■■ ■■■■■ ♦♦♦♦♦ ♦• ✞✞✞✞	●● ■■ ♦♦♦♦♦ 	 • ♦♦•	 • 	 • 			
F9/10	M3 distal cusp in wear, 9G to 10G	Soay Moufl, MxS Other min. Sc. Blackf CFP cross				 • 	 ■■ ♦ ✞✞	 • ■■ ♦♦♦♦ 	● ○ ■ ♦• •	 ♦♦• 	● • 	 • 		
F/G		Soay Moufl, MxS Other min. Sc. Blackf CFP cross			 • 		• ■• ♦• ✞	• ■• ♦ 	●●• • ■ ♦♦♦♦ •	●• • • ♦♦ 	 • 			
G	M3 at 11G, M2 at 9A	Soay Moufl, MxS Other min. Sc. Blackf CFP cross					• • • •	• • ♦• 	●●● ■■■■• ♦♦♦♦♦ ♦♦ •	●• ■• ♦♦♦♦♦ ♦• •	●●●● • ■ ♦♦♦♦♦ ♦♦♦♦♦• ✞✞✞✞•	●● • ■• ♦♦♦• ✞✞	●• ♦♦♦♦♦• ✞✞✞✞✞ ✞•	■■
H	M3 at 11G, M2 > 9A	CFP cross										•	•	•

Each main symbol represents two records.

Fig. 13. Mandible stages by breed, age classes 27 to 84 months.

	13 mo			24 mo	
	f	m		f	m
C6+	4	2	D5	1	
D12	20	5	D5/7	3	
D34	20	3	D6+	7	2
D4/5	3		E12	20	4
D5	1	1	E3+	5	1
D5/7	1		F5/8	1	

Butser sheep, mixed breeds.

Fig. 14. Mandible stages observed in ewes and rams of 13 and 24 months.

												P4	**dp4**															
	8											shed	shed						1	4								
	3											15A	21/23						1	16								
	29											14S	20						9	13								
	114	17	13	11	5		1	1				12S	18/19						10	16								
	5	2	1	5	3		1	1				9A	17					4	17	20								
	6	5	4	10	1		1					5/12W	16L					9	44	**39**								
	4	6	8	23	12	0	5	2				8A	15K					14	**25**	13								
	1	4	4	30	12	1	7	15	2			7S	14L			2	32	**42**	**57**	76	39							
				3	1							4A/7S	10/14			5	**33**	9	4									
				2	1		3	2	1			4A	13L		2	8	10	7	1		1							
				6	6	3	9	27	13			2A	7/13	5	10	**58**	22	1										
							1	11	12	1		UJ	7L	12	**23**	6												
							2	6	18	3	2	EH	6L	16														
								1	3	2		shed	2-4	20														
					1		2	5	35	26	714	dp4 wr	nye/U/J	24														
M3	11	10	9G	7/8	5/6	6/7	5A	3/4	1/2	EJ	nye			nye	EJ	1/2	3/4	5A	6/7	8A	9A	10/	12	13	14	15	sh	**M1**
	G	G		G	G	A		A	A							A	A		A			11	A	A	A	A		
													E/J					12	**34**	9	1							
													1/2A					2	12	**31**	6							
													3/4A						6	**84**	21							
									2	6			5A							28	**43**							
				1	1		4	27	**50**	**22**			6/7A							37	**118**							
		0	3	30	**21**	1	**13**	**31**	22	3			8A								**126**							
	169	**34**	**32**	**61**	17	3	13	9	2				9A								**241**	14	63	1	4	20	6	
	2												12A													2		
	1												15A												1			
													M2															

Reading from the top right quadrant working clockwise, wear stages are shown against the next-erupting tooth. The median value (highlighted and bold) is shown for the column or row of the later erupting tooth, e.g., the M1 column in the dp4/M1 quadrant. There is considerable summarising of data (for dp4 to M2, grouped stages were allotted in the proportion of the adjacent stages; for M3 and P4, because of their greater number, grouped stages were allotted equally, e.g., 9/11G a third each to 9G, 10G, 11G); nye – not yet erupted. (Totals in each quadrant may not tally because of rounding, some records do not have data for all four teeth, nye is only shown for dp4/M1 and M3/P4, and P4 is not shown in the 1st quadrant).

Fig. 15. Relative wear of dp4, M1, M2, M3 and P4.

	P4 in wear M3 unworn	P4 unworn M3 in wear	M3 eruption ave. (95%)	P4 eruption ave. (95%)
Sheep, this study	0	68	21 (18–24) mo	25.5 (22–33) mo
Sheep, Halstead *et al*, p.c.[1]	1[2]	2		
Goats, D&P 1979, 1982	all(?)	0?	25 (21–28) mo[3]	22 (19–24) mo[3]
Goats, Noddle 1974	7	0		
Goats, Bullock & Rackham 1982	2	0		
Goats, Halstead *et al*, p.c.[1]	9	0		

[1] Halstead *et al* 2002, and pers. comm.; [2] P4 in wear but only half up; [3] Deniz and Payne's Table 2 (1979) and Figs. 20 and 23 (1982), females; males one month earlier; 'P2-4 erupt before M3' (1979, p.155).

Fig. 16. Comparison of sheep with goats, where one only of P4 and M3 are in wear, and M3 and P4 eruption times.

Stage	Sub-divided stage	The majority of records[1]	**All records** except outliers[2]	central point	Payne 1973 estimates	Turkish goats based on D&P 1982[3]
A		0–1 mo[4]	**0 – 1 mo[4]**	0 mo[4]	0 – 2 mo	
B		1–3 mo	**1 – 4 mo**	2 mo	2 – 6 mo	– 5 mo
C		3–12 mo	**3 – 13 mo**		6 – 12 mo	3 – 14 mo
	C1/2	3–5 mo	**3 – 7 mo**	4 mo		
	C3/4	5–8 mo	**4 – 9 mo**	6.5 mo		
	C5	6–9 mo	**6 – 10 mo**	8 mo		
	C6+	8–12 mo	**8 – 13 mo**	10 mo		
D		10–24 mo	**10 – 27 mo**		1 – 2 yrs	11 – 30 mo
	D1/2	10–13 mo	**10 – 14 mo**	12 mo		
	D3/4	12–17 mo	**11 – 20 mo**	15 mo		
	D5	14–20 mo	**13 – 22 mo**	17 mo		
	D6+	18–24 mo	**14 – 27 mo**	20 mo		
E		20–36 mo	**19 – 54 mo**		2 – 3 yrs	24 – 47 mo
	E1/2	20–30 mo	**19 – 36 mo**	23 mo		
	E3+	22–36 mo	**21 – 54 mo**	30 mo		
F		2½ – 4½ yrs	**2½ – 6 yrs**		3 – 4 yrs	33 mo – 6 yrs
	F5/8	2½ – 4 yrs	**2½ – 4½ yrs**	3 yrs		
	F9/10	3½ – 4½ yrs	**3½ – 6 yrs**	4 yrs		
G		4½ – 7+	**4 –** e.9		4 – 6 yrs	4 – 7½ yrs
	Ga	4½ – e.6½	**4 –** e.7	5½ yrs		
	Gb	4½ – e.8	**4** – e.9	e.6½ yrs		
H		7+	e.6 – e.11+	e.8	6 – 8 yrs	5 – 9½ yrs
J		none	e.8 – e.13+	e.10	8 – 10 yrs	7 – 10+ yrs

Figures based on: [1] the central two-thirds and [2] the 95% from the columns of Table 9; the central point is taken from visual study of the rows on Table 9. [3] using, as closely as possible, the same method as 'All records except outliers'. [4] – archaeological material at A may include pre-natal lambs; the estimated central point may most sensibly be taken as 0 months. 'e.' – estimated, see also Table 18. (Payne's late stage 'I' is re-named as 'J').

Fig. 17. Mandible stage summary.

	years	4, 4½	5, 5½	6, 6½	7, 7½	8, 8½	9	10	11	12+
Sheep, this study	<H	109	86	47	4					
	H			2H	H					
St. Kilda Soays	<H	1	3	2	2	2	2		1	
Clutton-Brock *et al* 1990	H				1H		1H		1H	
Shetlands	<H	12	6	5						
Davis 1996, 2000	H or J			4H 1J						
Museum study sheep	<H	17	6	5						
Moran & O'Connor 1994, p.c.	H or J	2H	1H	7H		2J	1H 3J			
Butser Shetland ram (?9 or 10 yrs)							1H			
Awassi sheep, Weinreb/Sharav 1964									1J	
Suffolk cross ewe, Griffith, p.c.										1J (16yrs)

Grant's stage 'h' is taken as equivalent to 9A (or 11G), for defining G, H and J.

Fig. 18. Erasure of the infundibula in comparative sources; known-age sources, stages H and J.

				G	H	J	ratio (%)	F M1>9A	Ga	Gb
Sheep, this study	(no old sheep)	UK	Modern	152	3	0	98: 02: 00	4 +*	57	95 +*
sheep(goat)	Grant 1982, Table 3	UK	RB-med.	213	62	12	74: 22: 04	36	31	182
sheep(goat)	Dobney *et al* 1996, Table 33	UK	Med.	35	6	3	80: 14: 07			
sheep/goat	Payne 1973, Fig. 12	Turkey	Hell.-med.	15	7	6	54: 25: 21			
sheep	Payne 1973, Fig. 14	Turkey	Modern	5	5	1	46: 46: 08			
sheep	Halstead, p.c.	Greece[1]	Late neo.	72	53	22	49: 36: 15	11	2	46
goat	Halstead, p.c.	Greece[1]	Late neo.	31	6	2	79: 15: 05	12	0	21
sheep + goat	Halstead, p.c.[2]	Greece[1]	Late neo.	212	122	29	58: 34: 08			

* - 4 definites, plus 9 at F/G, see text, 'Sheep aged two to seven years old'; [1]- Makrigialos, N. Greece (phase I early Late Neolithic); [2] including grouped jaws (e.g. G/H), assigned proportionately.

Fig. 19. Erasure of the infundibula in other sources; the ratio of G, H and J, and erasure of M1.

Age in years	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**19**	
Year of birth	**2002**	**2001**	**2000**	**1999**	**1998**	**1997**	**1996**	**1995**	**1994**	**1993**	**1992**	**1991**	**1990**	**1989**	**1988**	**1987**	**1986**	**1984**	
Females	2109	2178	2046	1799	1841	1505	1427	1326	1193	867	162	76	61	29	16	2	1	1	16639
Males	1518	909	349	213	242	207	192	181	174	163	6	3	1		1	1			4160
Total	3627	3087	2395	2012	2083	1712	1619	1507	1367	1030	168	79	62	29	17	3	1	1	20799

Combined breeds: Boreray, Castlemilk Moorit, Manx Loghtan, Norfolk Horn, North Ronaldsay, Portland, Soay and Whitefaced Woodland; data from RBST; E. Henson, Grassroots System, pers. comm. (information from all breeders who made a return in 2002).

Fig. 20. The age of live registered Rare Breed sheep, in the UK, in January 2003.