

# *Circaea*



## Circaea

---

*Circaea* is the Journal (formerly Bulletin) of the Association for Environmental Archaeology (AEA) and—as from Volume 4—it is published twice a year. It contains short articles and reviews as well as more substantial papers and notices of forthcoming publications.

The *Newsletter* of the Association, produced four times a year, carries news about conferences and the business of the Association. It is edited by Wendy Carruthers (Sawmills House, Castellau, Pontyclun, Llantrisant, Mid Glamorgan CF7 8LP, U.K.) and Vanessa Straker (Department of Geography, University of Bristol, Bristol BS8 1SS, U.K.), to whom copy should be sent (on 5.25 or 3.5-inch floppy disk in IBM-PC format as *WordPerfect*, *Word* or ASCII files to Wendy or by e-mail or as hard copy, to Vanessa).

**Editorial policy for *Circaea* is to include material of a controversial nature where important issues are involved. Although a high standard will be required in scientific contributions, the Editors will be happy to consider material the importance or relevance of which might not be apparent to the editors of scientific and archaeological journals—for example, papers which consider in detail methodological problems such as the identification of difficult bioarchaeological remains.**

This issue of *Circaea* was edited and assembled by Allan Hall and Harry Kenward at the University of York, England. It is distributed free to members of the AEA. Annual subscriptions to the Association are currently £12 for ordinary individual members, £6 for students and unwaged, and £18 for institutions. The institutional subscription to *Circaea* is also £18.

At present, copyright resides with individual authors and with *Circaea*, on the understanding that *Circaea* may reprint material without consulting the author, and that the author may reproduce their own articles without permission. This is intended to circumvent the complexities of photocopying restrictions. *Circaea* waives restrictions on multiple copying for *academic* purposes by anyone but copies so made should not be sold.

*Circaea* is published by the Association for Environmental Archaeology, c/o Environmental Archaeology Unit, University of York, Heslington, York YO1 5DD, U.K. Enquiries concerning membership of the AEA should be sent to Dr Rebecca Nicholson, Membership Secretary, Association for Environmental Archaeology, c/o Department of Archaeological Sciences, University of Bradford, Bradford BD7 1DP, U.K. **Notes for contributors may be found on the inside back page of this issue.**

*Front cover: Headshield of the cladoceran, Monospilus dispar, from Giecz, Poland. From an original by Ilona Polcyn.*

# Application of Cladocera analysis in archaeology

Ilona Polcyn

*Institute of Geological Sciences, Żwirki i Wigury 93, 02-089 Warszawa, Poland*

## Summary

*The fundamental principles of the analysis of subfossil Cladocera remains are presented, together with a discussion of their application in Quaternary geology and archaeology. The paper concludes with a discussion of the results of employing this analysis on two Polish archaeological sites.*

## Introduction

Cladocera belong to the class Crustacea. They constitute one of the main elements of freshwater fauna. Their bodies are covered with chitinised carapaces which remain preserved in bottom sediments, either after moulting or after the organism's death. They live both in small (temporary) basins and larger ones. Particular species inhabit different parts of the basin. Some stay near the bottom, whilst others inhabit the pelagic zone, but the majority of Central European species are littoral forms.

Some Cladocera feed on bacteria, algae, and organic detritus which they filter from the water and scrape from submerged surfaces. There are, however also a few predatory species. Cladocera are found over vast areas of the Earth and their remains are recorded in periods as early as the Eemian (Last Interglacial (Frey 1962).

Features which enable an accurate determination of the species are contained in the following subfossil fragments of the carapace: headshields, antennules, elements of the post-abdomen, post-abdominal claws, and ephippia; they exhibit qualities which allow for a proper species identification (Fig. 14). The determination of the number of remains and their species is fundamental to a reconstruction of Cladocera communities living in a basin during the accumulation of a sediment from which the analyzed sample was collected. Particular species are characterized by definite ecological requirements (Frey 1960); and, consequently, the reconstruction of the species composition of Cladoceran remains in the sample is of great importance in determining the conditions existing in the basin when the layer accumulated. Changes in the composition of the Cladocera remains,

presented according to the geological sequence, enable a reconstruction of the basin's history to be made. On the basis of the evolution of the existing ecological conditions, it is possible to speculate about climatic changes (Hofmann 1987).

## Cladocera and human activity

Eutrophication is a process typical for freshwater basins. It is a natural phenomenon defined as an increase in the concentration of biogenic substances in water. Its intensity depends on the degree to which food components flow in from the catchment as well as on the stage of geological development the lake has reached. The changes in trophic level are directly bound to changes in the conditions of the habitat, which, in turn, are followed by changes in the composition of zooplankton. When productivity is intensified, species preferring nutrient-rich water arrive (Crisman and Whitehead 1978). Of all Cladocera species, *Bosmina longirostris* is the main one indicating progress in eutrophication. Fluctuations in the occurrence of representatives of the family Bosminidae are closely connected with the changes in the trophic level of a basin.

Agriculture and stock-raising exert great influence on the process of enriching surface waters in food components and, consequently, accelerate eutrophication. When it is caused by human activity around a lake, this supply of nutrients is called anthropogenic (artificial) eutrophication.

A basin is a sensitive recorder of changes taking place in its catchment area. These changes are particularly evident on the temporal scale when, alongside natural

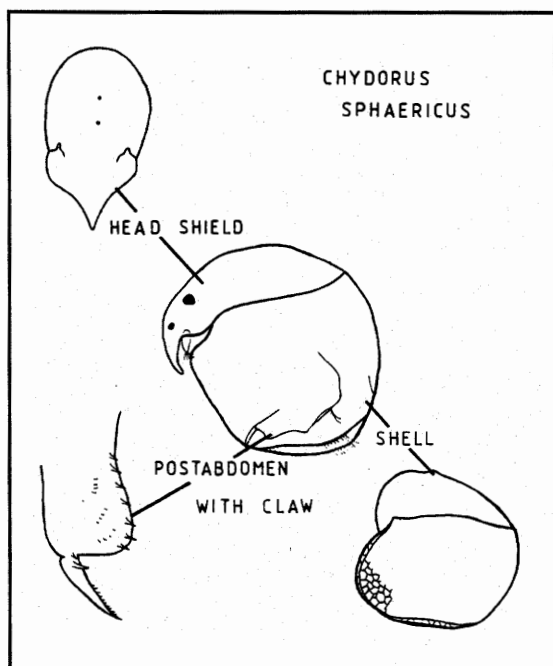


Figure 14. The relation of the various fossil fragments to the entire living organism (*Chydorus sphaericus*).

changes in trophic level, changes effected by humans are also recorded. These are connected with successive stages of colonisation around the lake. Human presence, marked by settlements, is not only limited to neolithic and ensuing cultures which have also been reflected in pollen diagrams.

Cladocera analysis also reveals more subtle changes in the environment triggered by the presence of pre-agrarian peoples. Their activity did not have a pronounced effect on flora and thus remains unmarked on pollen diagrams. However, it was not completely neutral to the natural environment. The encampments of pre-agrarian communities and their activities were a significant source of nutrients to the environment. Frequently, these sources were so pronounced that they may have caused an increase in lake trophic level and effected changes in the aquatic environment which were, finally, recorded in bottom sediments. It is possible to perceive and interpret these changes thanks to the reconstruction of Cladocera communities (Szeroczyńska 1991). Likewise, it is possible to trace environmental changes brought about by colonists who, in prehistory, made use of the waters of a lake or its shoreline. These colonists built shoreline and over-water settlements, bridges, dikes, piers, etc.

Another kind of information provided by the analysis of Cladocera concerns changes in water level. This is obtained by calculating the quantitative proportion of pelagic species to littoral ones (Mikulski 1978).

Cladocera analysis is used in complex palaeoecological investigations; it is also sometimes applied in archaeological research (Szeroczyńska 1981). Bog archaeological sites containing sediments of limnic origin are of particular importance here. Complex investigations of material collected directly from archaeological sites help to achieve a more complete reconstruction of living conditions of prehistoric communities.

Such investigations were carried out on a number of archaeological sites in Poland and enabled researchers to find new solutions. This refers particularly to such sites as Giecz (Polcyn and Polcyn 1994) and Moitajny (Polcyn, in press), which serve to illustrate the investigative potential of Cladocera analysis.

### Methods for analysing Cladocera

Material for analysis may be collected from cores of limnic sediment as well as directly from the walls of archaeological trenches. Sampling strategy depends on the information desired. Usually 1 cm<sup>3</sup> of the sediment is analyzed. A laboratory analysis is carried out according to the generally accepted procedure (Frey 1986). A sample is surveyed by means of a microscope (Fig. 15) and all Cladocera remains are counted.

The results of this observation are presented in tables which contain the absolute number of remains found in a 1 cm<sup>3</sup> sample of sediment. This, in turn, forms the basis for further calculations. Diagrams representing the absolute presence of individual species in a sample are a graphic representation of achieved results.

### Application of Cladocera analysis on archaeological sites

#### (i) Giecz

The Early Medieval stronghold in Giecz (Central Wielkopolska) is situated on the rim of the valley of the Moskawa River which, in this place, used to form an overflow-arm in the shape of a long, narrow lake. At that time,

the lake provided natural protection for the stronghold. Today, it is a entirely overgrown basin containing 10 metre-thick sediments. In the Early Middle Ages, the stronghold was connected to the settlement located on the opposite shore of the lake. In those days, the settlement was known for its fairs and a Romanesque church, which has survived to the present day. The two places were joined by a dike or a bridge, the remains of which are still visible on the surface as two rows of piles stuck into the ground close to one another.

Archaeological excavations carried out on these dike/bridge relics revealed the structure of the object, which was not subject to unequivocal interpretation. Any final conclusions were to follow the completion of other analyses (i.e. analysis of pollen, plant macrofossils, and Cladocera). The analysis of Cladocera was applied, among others, to two cores, one extracted from inside the wall of an excavation, and the other from inside the object itself, i.e. from between the rows of piles. The results of the study allowed conclusions to be drawn about the conditions existing in the basin before the dike/bridge had been constructed. They also helped to determine finally the function of the object. The first of these conclusions was based on an analysis of species composition of Cladocera remains in particular layers of sediments, whereas the second was based on the curves of total contents of Cladocera in samples. The results gave rise to the following division of layers (Fig. 16).

**Open lake** The undisturbed lake environment is mirrored in the lowest layers formed under conditions of undisturbed sedimentation. Many Cladocera species, at that time, found very favourable living conditions. The number of remains in 1 cm<sup>3</sup> reached 120,000.

**Bridge** The curve of the absolute presence of Cladocera in both cores shows significant deviations which reflect disturbances in sedimentation. At the same time, species composition is still characteristic of the fauna of eutrophic lakes, and the number of remains is high. These layers contain rich archaeological material; there is, however, no evidence of any wooden horizontal constructions.

**Dike** Following the disturbances in the functioning of the bridge, both curves show a

drastic fall. The total content of Cladocera in some samples is zero; however, species composition in the other ones remains basically unchanged. It points to different sedimentation conditions which do not necessarily indicate different conditions of lake habitat.

Over the extent of the dike, the course of the curve for both cores is not identical. In the northern core, following a short period of fall, the curve rises again, indicating an aquatic environment. In the southern core, the low values remain throughout, almost to the topmost samples. In the layers discussed, a wealth of archaeological material was discovered. It was here that wooden structural elements were also deposited. The analyzed sediments accumulated during the process of filling in the construction and had as their purpose the creation of a surface extending over the level of the water. After a short period of the structure's functioning along its whole extent, between the rows of piles (a falling curve in both cores), only a part of the structure was used (a rising curve in the northern core and a breakdown in the sedimentation of the northern core). During higher water levels, this part was also inundated, which allowed Cladocera remains to get into the sediment.

**Inundation and overgrowth** The content of Cladocera in the topmost samples increases, after which it decreases with a simultaneous change in the species composition. Species remained which could withstand very unfavourable habitats. During this period, the dike ceased to exist and the lake gradually turned to land.

## (ii) *Mołtajny*

Cladocera analysis was employed on material originating with a La Tène settlement of the Western Balt Barrow Culture on the island in Lake Arklickie in north-eastern Poland. A core of sediment from the wall of an excavation trench was analyzed (Fig. 17).

Twenty species of Cladocera were identified. These belonged to three families: Bosminidae, Chydoridae and Sididae. The majority of species found in the lowest layers of the sediment sequence are typical of shallow lakes and occur rarely and in small amounts—up to approximately 4,000 remains per cm<sup>3</sup>. An increase in the number of remains recorded in the upper layers suggests an enrichment of the

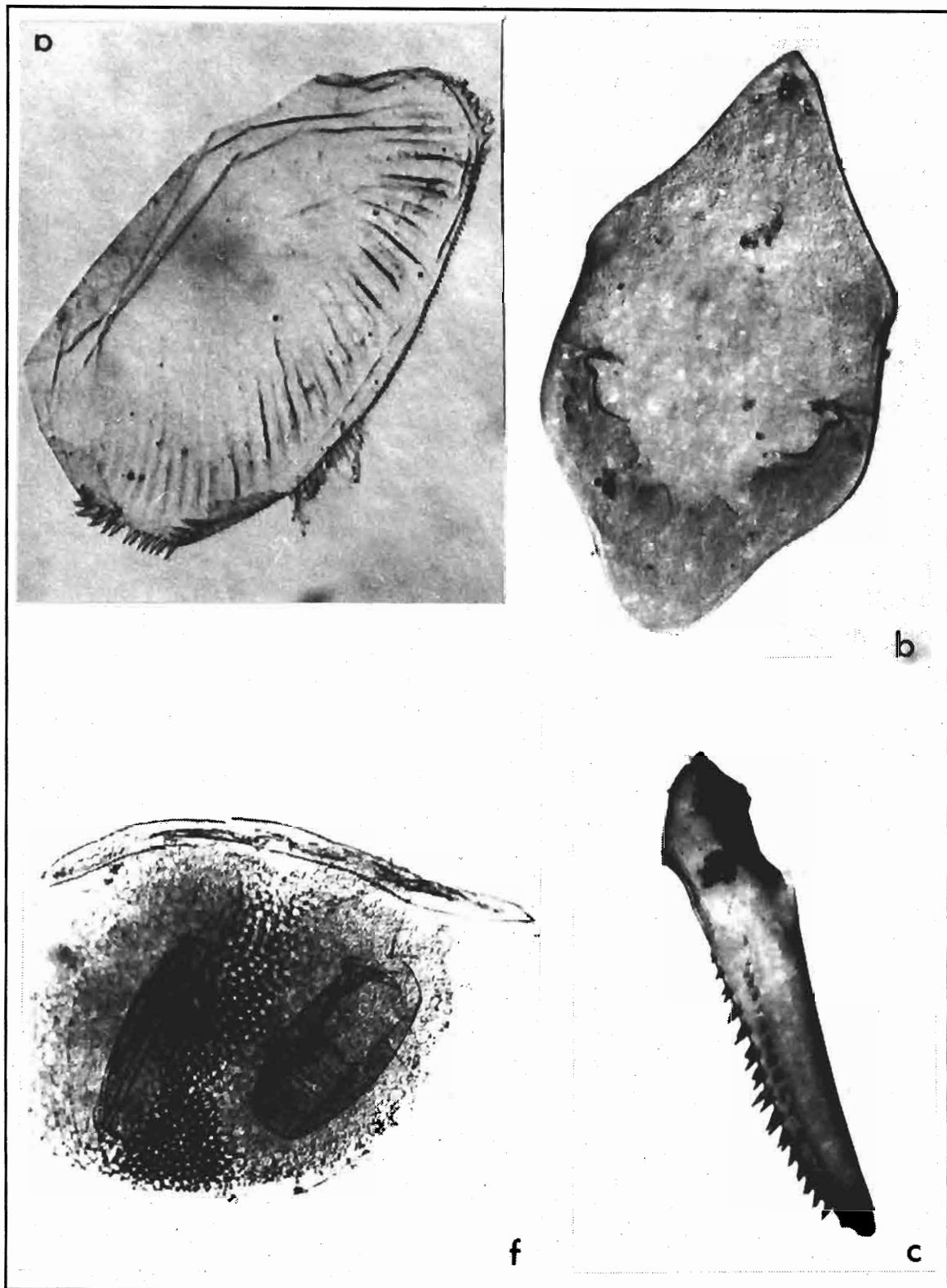
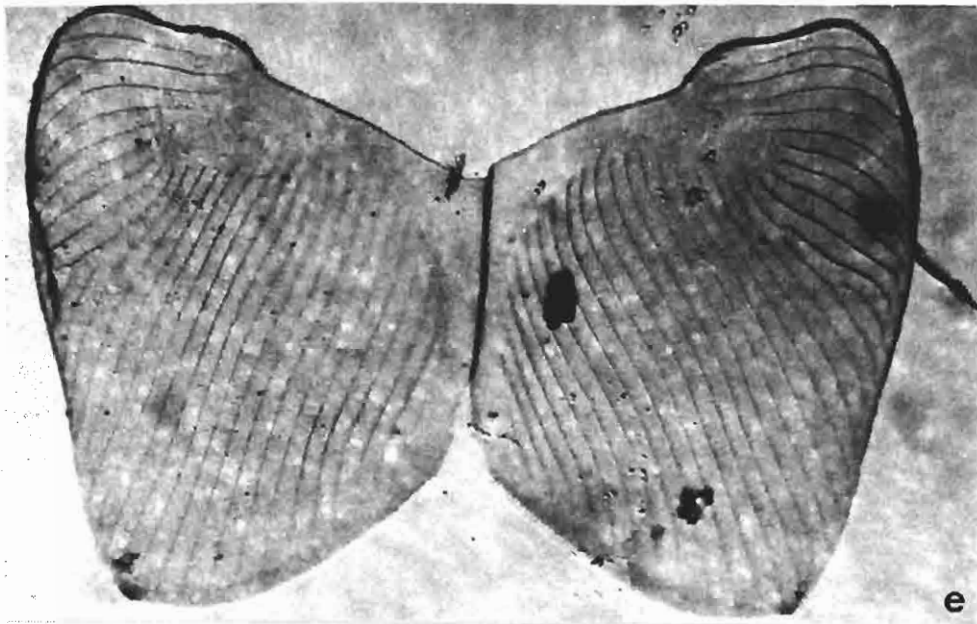
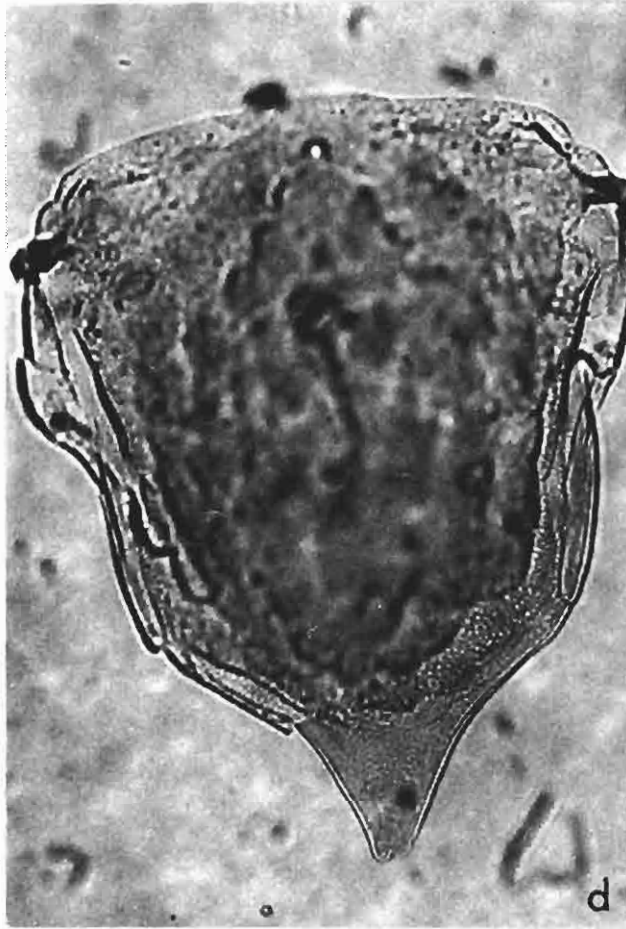


Figure 15 (above and opposite). A microscopic view of the remains of several Cladocera species from Giecz, Poland. a - *Peracantha truncata*: shell, x 140; b - *Alona affinis*: head shield, x 140; c - *Camptocercus rectirostris*: postabdomen, x 200; d - *Monospilus dispar*: head shield, x 140; e - *Acroperus harpae*: shell, x 140; f - *Daphnia* sp.: ephippium, x 140.



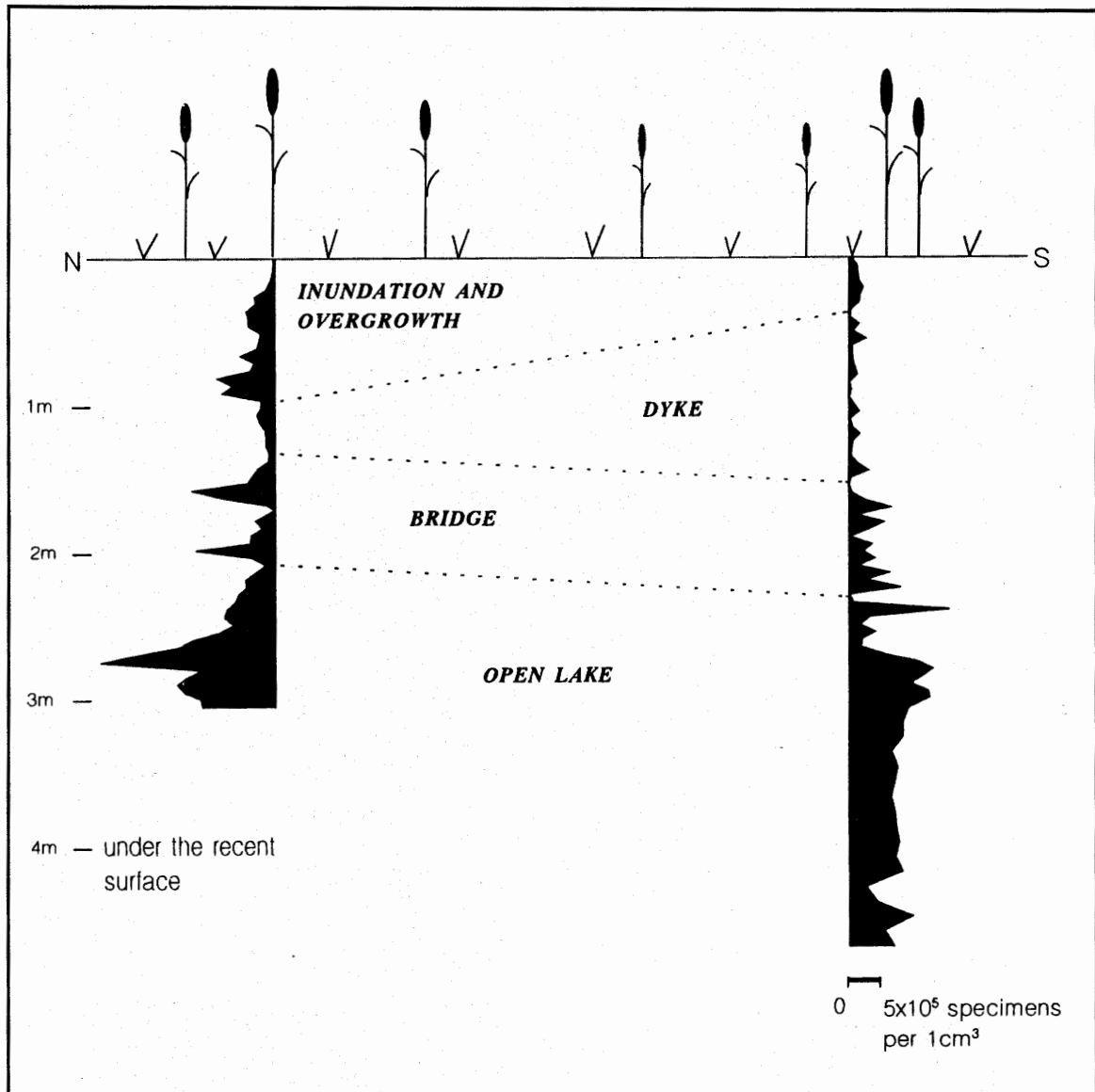


Figure 16. A reconstruction of the Early Medieval lake crossing in Giecz based on Cladocera analysis.

habitat; at the same time, the species composition remains unchanged. These conditions guarantee a maximum development of such littoral and eutrophic species such as *Bosmina longirostris*, *Chydorus sphaericus*, *Alona rectangularis*, *A. guttata*, *Alonella nana*. It is possible to trace a relation between the sudden breakdown in the sedimentation process of Cladocera remains and the appearance of elements of wooden construction which marks the beginning of the culture layer deposition. This indicates that the people of the Western Balt Barrow Culture made use of the shoals to build their settlement. The grid-like structure of the settlement manifests the characteristics of an artificial island. This is confirmed by a

culture layer formed above the water's surface (no Cladocera remains were found). The results of the Cladocera analysis preclude the possibility of a pile dwelling settlement, because in such an event, the culture layer would, under aquatic conditions, have accumulated mainly at the bottom of the lake.

### Conclusions

1. Cladocera are often the most abundant of the crustaceans preserved in lake sediments. This makes the analysis of subfossil Cladocera remains a prominent method of Quaternary palaeolimnology and geology.



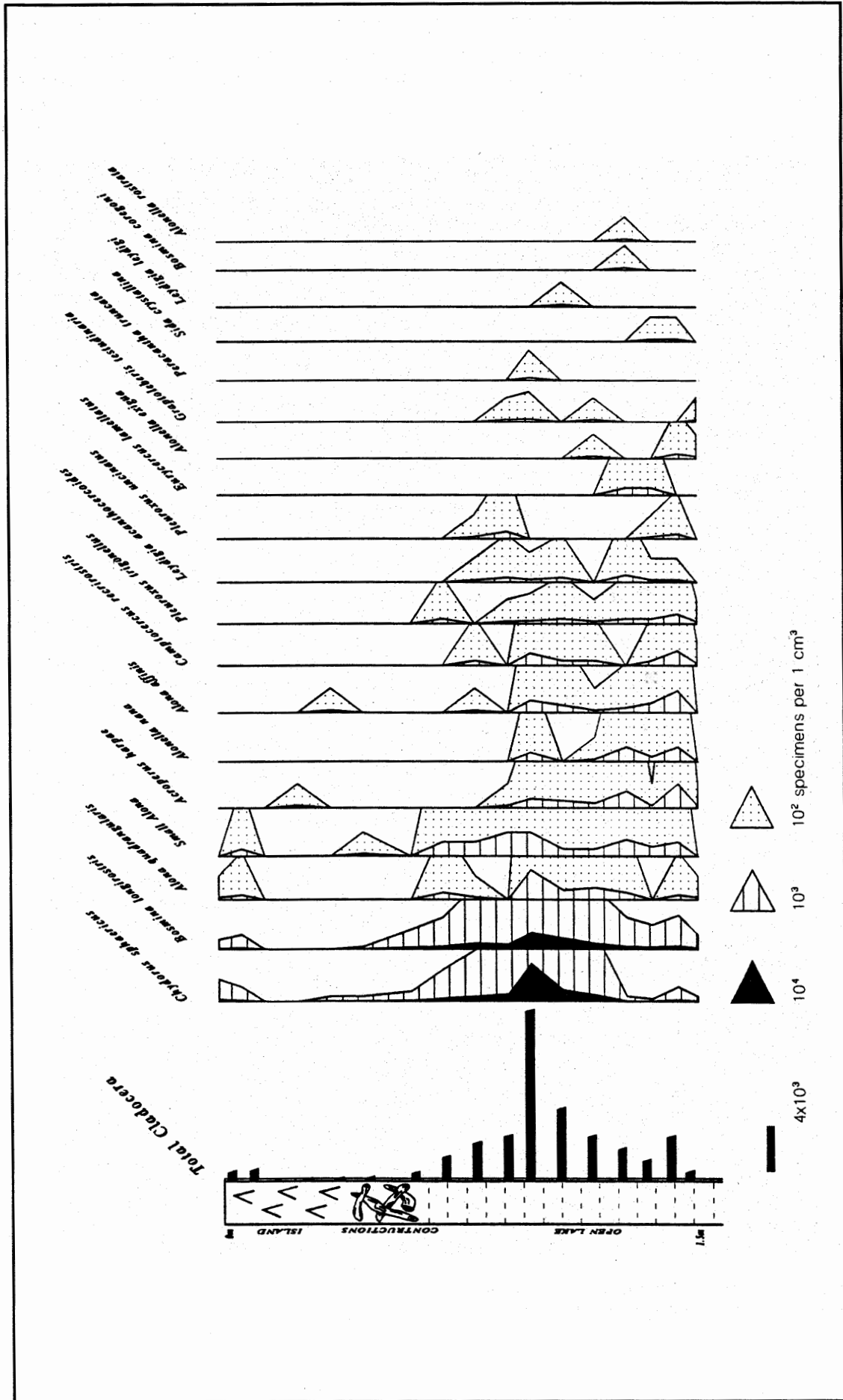


Figure 17. Quantitative and qualitative distribution of Cladocera in the Mottajny profile.

2. The ecology of modern Cladocera may be used for the interpretation of their subfossil assemblages.

3. Periods of abundance can be associated with climatic or cultural changes in the drainage basin.

4. Changes in the abundance of Cladocera and in species composition may lead to conclusions as to water level changes, water chemistry, changes in lake productivity, and the development of lake flora.

5. Employing Cladocera analysis on two archaeological wetland sites in Poland provided information allowing for much clearer interpretation of the site itself.

### Acknowledgments

I would like to thank Professor Teresa Madeyska and Dr Krystyna Szeroczyńska (Institute of Geological Sciences of the Polish Academy of Sciences, Warsaw) and Jacek Wierzbicki (Institute of Prehistory, A. Mickiewicz University, Poznań) for their critical reading of the manuscript. I am grateful to Andrzej Bursa and Jacek Fabiszak (School of English, A. Mickiewicz University, Poznań) for translating the text into English. Special thanks to my husband Marek for all his help.

### References

Crisman, T. L. and Whitehead, D. R. (1978). Paleolimnological studies on small New England (USA) ponds. Part II. Cladocera community responses to trophic oscillations. *Polish Archives of Hydrobiology* 25(1-2), 75-86.

Frey, D. G. (1960). The ecological significance of cladoceran remains in lake sediments. *Ecology* 41, 684-99.

Frey, D. G. (1962). Cladocera from the Eemian Interglacial of Denmark. *Journal of Paleontology* 36, 1133-54.

Frey, D. G. (1986). Cladocera analysis, pp. 667-92 in B. E. Berglund (ed.) *Handbook of Holocene palaeoecology and palaeohydrology*. Chichester: Wiley.

Hofmann, W. (1987). Cladocera in space and time: analysis of lake sediment. *Hydrobiologia* 145, 315-21.

Mikulski, J. St. (1978). Value of some biological indices in case historic of lakes. *Verhandlungen der Internationalen Vereinigung Limnologie* 20, 992-6.

Polcyn, I. (in press). Skład gatunkowy kopalnych wioślarek z rdzenia osadów biogenicznych wydobytego w obrębie osady ludności kultury kurhanów zachodnio-bałtyjskich w Mołtajnach, stan. 1 (Species composition of Cladoceran remains in the core of sediments from within the Western Balt Barrow Culture settlement in Mołtajny, site 1). *Acta Universitatis Nicolai Copernici, Archeologia* 24, *Archeologia podwodna* 4. Toruń.

Polcyn, I. and Polcyn, M. (1994). Stratygrafia mostu/grobli w Gieczu w oparciu o morfologię warstw, układ konstrukcji i wyniki analizy wioślarek (Cladocera) (Stratigraphy of the dike/bridge in Giecz according to its sediment morphology, archaeological constructions and Cladocera analysis). *Studia Lednickie* 3, 206-11.

Szeroczyńska, K. (1985). Cladocera jako wskaźnik ekologiczny w późnoczwartorzędowych osadach jeziornych Polski Północnej (Cladocera as ecologic indicator in late Quaternary lacustrine sediments in Northern Poland). *Acta Palaeontologica Polonica* 30(1-2), 3-69.

Szeroczyńska, K. (1991). Impact of prehistoric settlements on the Cladocera in the sediments of Lakes Suszek, Błędowo, and Skrzetuszewskie. *Hydrobiologia* 225, 105-14

*Revised disk version received November 1994 (the Editors offer sincere apologies to the author for the delay in the publication of this paper).*

## When is a time-trend not a time-trend? Scale and profile at Bronze Age Phylakopi (Melos)

Nick Winder

McDonald Institute for Archaeological Research, Downing Street, Cambridge CB2 3DZ, U.K.

### Summary

*This paper distinguishes two characteristics of a bone assemblage: its scale (or size) and profile (or composition). The investigation of bone assemblages often involves standardising the data to control for variation in scale so that the profile of assemblage subsets can be compared and contrasted.*

*A formal multiplicative or log-linear model of assemblage formation is proposed which implies that the standardisation methods commonly chosen by archaeozoologists (percentages, proportions and means) are inappropriate; they violate the independence of potentially distinct assemblage formation processes. When a standardisation method is needed (and it is not always needed) archaeozoologists should consider taking logarithms of bone frequencies and expressing each as a deviation from the assemblage mean.*

*Two analyses using this approach are presented as part of a re-assessment of the animal bone data from Bronze Age Phylakopi (Melos). They suggest that the time-trends Gamble observed may be artefacts of a partial excavation strategy and of taphonomic variation. A third analysis that does not require standardisation appears to confirm this view. Prospects for further analyses using such arguments are explored.*

### Introduction

The animal bones from Renfrew's excavations at Phylakopi were identified and described by C. S. Gamble who addressed three questions (Gamble 1982; 1985):

- (1) What is the general character and composition of the whole animal bone assemblage?
- (2) What variation in assemblage composition can be observed through time?
- (3) What can assemblage composition tell us about the spatial localisation of contemporary activities, particularly in the vicinity of the Sanctuary?

The questions were answered by setting out explicit assumptions and generalisations about the environment and the range of subsistence behaviours it could sustain, and building an interpretive paradigm for the bone data from these assumptions. Then the data were partitioned into classes on the basis of time phase or spatial location within the sedimentary matrix and examined for patterns

among these subsets. These patterns became the empirical evidence which was presented and interpreted.

Thus, Gamble argued from historical and environmental evidence that the maintenance of large numbers of cattle would have been impracticable given the periodic summer droughts and restricted pasturage available and that the consumption of meat at Phylakopi must have been a rare event, possibly restricted to public festivals and sacrifices (Gamble 1982, 161). He also noted the archaeological evidence for increased nucleation in the settlement pattern and concentrated his early attention on the search for the palaeoeconomic correlates of this nucleation.

Gamble found evidence of an increase in the relative abundance of cattle from the pre-city phase to phase III. In Phylakopi IV a slight reduction in cattle was observed. This pattern was interpreted as evidence that the nucleation of the site caused an increased demand for animal traction. The subsequent decrease in cattle is attributed to the establishment of donkeys as preferred beasts

of burden. The rarity of donkey bones (two bones only from phase IV) may reflect their disposal outside the settlement boundary (which is the common modern practice).

Gamble (1985) studied intra-stratum variation in the vicinity of the Mycenaean Sanctuary. He noted that the size of bone fragments between floor levels is generally smaller than that from post-abandonment fills and argued that large fragments would have been removed by routine sweeping. After abandonment, the assemblage changes somewhat and in some regions cattle predominate (at least by weight). It should be noted, however, that cow skeletons are appreciably heavier than those of sheep or pig. In this later work, Gamble distanced himself from the view that the Sanctuary would have formed the focus for public redistribution of meat which he now believed would have been environmentally unsustainable and for which he could find no evidence.

### Archaeozoology as the interpretation of cross-classified data

The bones were split into meaningful subsets and patterning manifest between these was used to make generalisations about changes in animal exploitation through time and through contemporary space. This required the definition of a number of classificatory variables, or *factors*, that described the way the assemblage was to be split. Time phases, features, trenches and taxonomic groups are all instances of classificatory factors. The interpretation of the data hinged on the assumption that patterns manifest between designated time phases represented time-trends while patterns manifest within a given phase had a purely behavioural significance. In the remainder of this paper I will argue that this assumption, although intuitively attractive, may not actually be justified. In particular, I will present evidence that it is not supportable at Phylakopi.

Imagine a trench through an urban site in which two phases produce strikingly different assemblages. In the first there might be a mixed assemblage of sheep and pigs, for example, while in the second pigs predominate. 'Classical' archaeozoological method would encourage us to interpret this pattern as a time-dependent shift in human subsistence from a sheep-and-pig to a pig-based economy. Now imagine the same

pattern emerging from two trenches cut through contemporary levels. Suddenly there is 'obviously' a specialised pig processing area in one of the trenches. The only difference between the two interpretations is that in the former case we chose to ignore the possibility that temporal and spatial factors might be autocorrelated.

Classical archaeozoological analysis has been underpinned by an insupportable *unifactorial* assumption which holds that the way one partitions an archaeological assemblage somehow determines the meaning of patterns among the resulting subsets. Few archaeozoologists would dispute that this is unrealistic. Indeed, Gamble (1982, 166) expressed concern that the necessary assumptions of constancy in disposal patterns and uniformity of bone preservation may be unjustified.

Unfortunately it is widely believed that the only way to solve this problem would be to lay out a sampling frame and implement a random sampling strategy that ensured every possible combination of factors was sampled. Such a sampling strategy would impose unacceptable constraints on excavators who would surely object to being prevented from the further investigation of chance discoveries (like Mycenaean Sanctuaries, for example) by a table of random numbers.

Furthermore, even if an excavator was willing to contemplate such an approach, it would be hard to make it work on a real archaeological site. It is seldom possible to sample all time phases in an even-handed way because the distribution of standing features and the need to shore up baulks restrict access to the lower levels of a deeply stratified site. It is also very difficult to set up random sampling strategies for consecutive time phases when the only accessible regions of the lower phase are those at the bottom of trenches already cut through the upper phase. Since the mechanics of digging preclude the experimental solution to the problem, archaeozoologists, like many other 'specialists', feel they have to live with the unidimensional assumption regardless of the unease it causes.

In this paper I will try to show by a case study that a truly *multifactorial* analysis of bone data is feasible provided we pay attention to evidence of autocorrelations or 'interactions' between different classificatory factors. This allows a more rigorous investigation of manifest pattern without

imposing unacceptable demands on the excavator.

### Scale and profile in assemblage formation

Animal bones are seldom recovered from a site in the relative frequencies observed in the whole skeleton. In the course of moving from the ancient biosphere to the modern lithosphere some elements must have been removed or lost. Since archaeozoologists routinely encounter assemblages in which certain elements are consistently under-represented, we must conclude that bone destruction or loss is selective. It is a short step from accepting that different elements of the skeleton of a given animal will have differential survival probabilities to postulating that the elements of different animals may also be differentially preserved, though finding evidence to support this hypothesis is difficult.

The study of processes which convert a population of animals in the ancient biosphere into a population recovered from the modern lithosphere is called *taphonomy*. Variation in the taphonomic careers of different assemblages condition both the size (or *scale*) and composition (or *profile*) of the bone assemblage. Different types of process are believed to produce different signatures which can, in theory, be read in the profiles of assemblage subsets. Taphonomists classify formation processes by their cause and take care to distinguish the effects of scavenging from weathering or fluvial sorting, for example (see papers in Behrensmeyer and Hill 1980).

It is rare for an archaeological assemblage to be conditioned by only one formation process. Typically its taphonomic career begins with a *biotic* phase of degradation during which animals, plants and microorganisms draw out selected resources. As time passes and the entropy of the carcasses increases, biotic exploitation is attenuated and gives way to a *climatic* or weathering phase and ultimately to more gradual *edaphic* decay as soil percolates and the weight of accumulated sediments destroy the bones. On an archaeological site this process culminates in another short burst of biotic activity as the bones are excavated and some are lost or destroyed.

Individual bones, viewed in isolation, tell us little of archaeological interest except that

anatomical part  $x$  of species  $y$  was recovered from context  $z$ . However, populations of bones may bear the traces of readable taphonomic signatures which are of considerable interest though these may have been overwritten and obscured. In general, the most interesting formation processes are those from the biotic phase. We want to know about the selection and slaughter of animals, the relative abundance of species consumed, the spatial organisation of carcass exploitation, dismemberment strategy, and waste disposal, both through time and through contemporary space. Disentangling 'interesting' from 'uninteresting' taphonomic processes may be virtually impossible because both suites of processes may have similar effects on the assemblage. Archaeozoologists must deal with the assemblage, with the *effects* of a suite of processes rather than with their individual *causes*. Consequently, 'bone reports' can seldom be written with the certainty or clarity of interpretation achievable in taphonomy.

The usual way to interpret a bone assemblage is to split it into interpretable subsets and prepare the data to allow these subsets to be compared and contrasted. Observed patterning among subsets is sometimes interpretable in the light of known taphonomic regularities. In general, the taphonomic signatures we wish to decipher are coded into the profile of the assemblage; the scale is of secondary interest. It would clearly be of value to develop ways of processing assemblage data so as to remove or standardise the effects of scale without disrupting any taphonomic signatures coded into the profile. This is not difficult in practice but requires us to think clearly about the analytical implications of mundane data transformations.

Consider an artificial assemblage of two elements both of which are subjected to two statistically independent formation processes. ('Independence' means that the vectors are uncorrelated one with the other.) Formation processes represented by independent vectors will have analytically distinguishable effects.

If each formation process destroys a fraction of the population of bones we can write were  $A(1)$  and  $A(2)$  are the sizes of the

$$A(1) = PP(1) * B(1,1) * B(1,2)$$

$$A(2) = PP(2) * B(2,1) * B(2,2)$$

(1)

assemblage of elements 1 and 2, PP(1) and PP(2) are the sizes of the antecedent or potential populations of element 1 and B(1,1) and B(1,2) are the proportions of elements 1 and 2 destroyed by process 1. This multiplicative model of assemblage formation amounts to a definition of a formation process as some factor that removes a proportion of the bones it encounters.

Now suppose we have two assemblage subsets to compare which differ from each other both in scale and in profile. We start with the simple situation in which the profile of both potential populations is identical. Our task is to find a way of controlling for the differences in scale between the two populations that does not violate the statistical independence of the formation processes. A glance at equations (1) shows that expressing bone frequencies as percentages or proportions or subtracting mean element frequencies will not do, because this has the effect of dividing each formation process by the sums of products of all other processes:

$$\frac{A(1)}{A(1)+A(2)} = \frac{PP(1)*B(1,1)*B(1,2)}{PP(1)*B(1,1)*B(1,2)+PP(2)*B(2,1)*B(2,2)} \quad (2)$$

The solution is straightforward. Equations (1) describe a log-linear model of assemblage formation because taking logarithms of the element frequencies gives a set of linear equations (it may be necessary to add a small constant to all bone frequencies or to mask out elements which occur with a frequency of zero before taking logs):

$$\begin{aligned} \text{LOG}(A(1)) &= \text{LOG}(PP(1)) + \text{LOG}(B(1,1)) + \text{LOG}(B(1,2)) \\ \text{LOG}(A(2)) &= \text{LOG}(PP(2)) + \text{LOG}(B(2,1)) + \text{LOG}(B(2,2)) \end{aligned} \quad (3)$$

Once we have a model of assemblage formation expressible in terms of a suite of linear equations, the system becomes much more tractable because we can appeal to the large body of statistical theory relating to the

generalised linear model. In particular, we can remove the effects of differences in scale between assemblages with similar potential populations without violating the independence of the formation processes by expressing each logarithmically transformed frequency as a deviation from the assemblage mean. Assemblage composition data standardised in this way will have a mean of 0.0 and a non-zero variance.

The argument is completely general and can be extended to assemblages of more than two elements and more than two independent formation processes without modification. Assuming *n* formation processes acting on a potential population, these variances will satisfy:

$$V(A) = V(PP) + V(B1) + V(B2) + \dots \quad (4)$$

where V(A) signifies the variance of the assemblage, V(PP) that of the potential population and so on. Two assemblages drawn from potential populations with similar taphonomic careers will have similar values for V(A) in equation (4) (subject to sampling errors) because their respective potential populations will have identical variances and they will have been subject to similar formation processes.

Differences between logarithmically transformed assemblage variances can, therefore, be interpreted in terms of differences in the formation processes to which the respective PPs were exposed. There will be a general agreement between the number and severity of the formation processes in effect and the variance of the standardised assemblage.

When (as is usually the case) we have more than one assemblage vector to consider, these can be standardised using the method just described so as to bring all subsets onto a common scale with a mean of 0.0 and a variance and profile determined by its individual taphonomic history. In vector notation, we can write:

$$PROF = PP' + B1' + B2' + \dots + Bn' \quad (5)$$

where PROF is a standardised assemblage (or *profile*) vector, PP' is a standardised potential population (shared by all assemblage subsets) and B1' to Bn' are standardised formation process vectors that condition assemblage profile. Profile data can be processed further or used to form the input matrix for any multivariate statistical method based on the generalised linear model. These include such methods as regression analysis, correspondence analysis, principal components analysis, and discriminant analysis.

### More than one taxon

Throughout the argument it has been assumed that two PPs may differ in scale but will not differ in profile. There are circumstances under which this assumption is obviously valid. If, for example, an assemblage is defined as representing only one taxon, the potential population will consist of a set of whole skeletons.

Obviously the requirement that an assemblage must consist of at most one species is too limiting for routine analytical use and we must consider the possibility of handling assemblages of two or more taxa. Suppose we have such a population. We can now define an hypothetical population vector C, each element of which contains an arbitrary constant. We can now write:

$$PP = C + B \quad (6)$$

where PP is unstandardised and B is a 'formation process' that transforms an arbitrary vector with zero variance (C) into a 'real' potential population, PP. Since the vector C has zero variance, it disappears on standardisation and we obtain a revised version of (5):

$$PROF = B' + B1' + \dots + Bn' \quad (7)$$

where all vectors are standardised with a mean of 0.0. This analytical device allows us to extend the method to assemblages consisting of more than one taxon by expressing such purposive human actions as animal husbandry and the selection of animals for slaughter as virtual formation processes whose cumulative effects can be read by

comparing the profile of standardised assemblage data with that of an hypothetical or 'average' potential population with zero variance. (Readers unfamiliar with computer jargon may find the word 'virtual' confusing. By a 'virtual formation process' I mean something which, while not recognised as a formation process in the strict sense, nonetheless has the same impact on a potential population as a formation process.)

Once data have been standardised, it remains a matter of convenience whether we analyse them in their logarithmic form or exponentiate the standardised frequencies and handle them as log-linear variables. Re-exponentiating gives us an assemblage vector in which each element frequency has been divided by the geometric mean of all element frequencies.

### Analysing the Phylakopi data

This case study is based on a database which has already been published. The site's phasing, organisation, architectural features and small finds have also been described in the same volumes (Renfrew *et al.* 1982; 1985). Accordingly, the present paper will be restricted to describing the small number of variables needed to understand and interpret the results presented here. I have tried to keep the terminology used to describe phases, trenches and structures consistent with that already published wherever possible.

The analyses I wish to present relate to three aspects of the assemblage: utility as a food resource, the 'survivability' or toughness of skeletal elements under attrition, and variation in taxonomic composition between assemblage subsets.

### Factors used to classify the assemblage

#### Contextual variables

Gamble's archive described the specimens identified from all contexts in the course of excavation. These were recovered from a number of trenches spread over a wide area of the site. For the purposes of the present study it was convenient to group these trenches into a series of 'complexes' each of the constituent trenches of which is separated from its nearest neighbour within the complex by a narrow baulk. Similarly, seven chronological units were recognised, of which the first two

**Factor 1. Trench Complex**

Code	Description
1	The Sanctuary Complex: NLa-e, OLc, OLd, PLa and PK
2	North East of megaron: trenches II B & II C
3	South West of megaron: trenches II D and II E
4	South of megaron: trench II A
5	Trench II S

**Factor 2. Phase**

Code	Description	Excavator's code	Phase
0	Pre City phases	A1-A2	
1	First City	B	I
2	Second City	C	II
3	Third City	D	III
4	Late Helladic	E	IV
5	Late Helladic	F	IV

**Factor 3. Type**

Code	Description
1	Walls, foundations and footings
2	Floors
3	Pits
4	Sediments overlaying floor surfaces (mostly occupational debris and rubbish)
5	Make-up and fill
6	External contexts
7	Other

Table 2. Factors used to subdivide the assemblage from Phylakopi.

pre-city phases (A1 and A2) have been amalgamated here and Phase IV which was subdivided into sub-phases E and F was treated as two units. Each unit recognised in the present study was assigned a numeric code. Finally, in addition to complex and phase, the assemblage has been subdivided into a large number of 'levels' or features, each of which was assigned to one of a fixed number of 'types'. This gives us three different ways of splitting the assemblage summarised in Table 2.

Handling the bone data level by level resulted in very small assemblage subsets many of

Pig	Cow	Ovicaprid
Mandible	Mandible	Mandible
Maxilla	Maxilla	Maxilla
—	—	Atlas/Axis
Scapula	Scapula	Scapula
Humerus	Humerus	Humerus
Ulna	Ulna	Ulna
Radius	Radius	Radius
Pelvis	Pelvis	Pelvis
Femur	Femur	Femur
Tibia	Tibia	Tibia
Metapod	Metacarpal	Metacarpal
—	Metatarsal	Metatarsal
Astragalus	Astragalus	Astragalus
Calcaneum	Calcaneum	Calcaneum
Phalange 1	Phalange 1	Phalange 1
Phalange 2	Phalange 2	Phalange 2
—	Horn	Horn

Table 3. Anatomical part codes for principal taxa.

which yielded so few bones that any patterns would be swamped by sampling errors. Accordingly, every unique combination of the values of factors *Phase*, *Complex* and *Type* was treated as a minimal assemblage subset in its own right. The large number of levels from the whole site were thus resolved into 40 analytical units, each of which was uniquely defined by the contextual variables.

*Archaeozoological variables*

The records of bones of the major taxa (ovicaprid, cow and pig) were recorded using a modification of the coding scheme originally developed by the British Academy Major Research Project on the Early History of Agriculture in the 1960s. There have always been problems with this coding scheme (Winder 1986; 1991). In practice, not all of the variables were needed and a simplified subset of the data was prepared for the present study which only used four variables: Context, Species, Anatomical Part and Hand (left or right). The list of anatomical part codes was reduced to a set which were relatively abundant and could be considered as discrete and universally distinguishable even when broken (see Table 3).

Each element was divided into three states with regard to age at death, these were 0 (no data), 1 (immature) and 2 (mature). These categories were primarily intended to indicate



	Caprid	Pig	Cow
<b>Phase code</b>			
0	742	562	195
1	713	610	237
2	718	574	645
3	703	626	591
4	822	586	460
5	796	435	618
1-2	443	32	100
3-4	591	202	352
<b>Trench</b>			
1	779	587	615
2	721	748	550
3	609	192	204
4	678	458	667
5	638	190	314
<b>Context type</b>			
1	724	538	705
2	324	91	38
3	685	477	513
4	706	579	622
5	653	567	608
6	726	577	346
7	665	419	411
<b>Whole assemblage</b>			
	686	593	561

Table 4 Phylakopi: bone utility by phase, trench and context type.

whether bones had survived sufficiently well for age data to be had. Information on age at death was of secondary interest in the present study.

Thus only a small subset of Gamble's field data was selected for re-examination. Other variables employed by the coding scheme were examined before the decision to rationalise the archive was taken. Some variables were ignored because the coding scheme could not furnish the fine-grained information required but the only occasion this rationalisation reduced the usefulness of results was when considering general utility indices (see below).

### Analysis 1: measuring general utility

Ethnographers and taphonomists have studied the disposition of meat and fat resources on the animal carcass and have tried to relate these to butchery practice. In general, it has

Phase code	Complex	Type	Sum of squares
0	2	1	62.026
0	2	6	64.834
0	3	5	9.942
1	2	1	33.848
1	2	2	6.972
1	2	4	58.945
1	2	5	11.768
1-2	3	4	31.097
2	1	1	51.930
2	1	2	4.415
2	1	4	4.415
2	1	7	63.045
2	2	3	53.853
2	2	4	19.941
2	2	5	10.226
2	3	5	34.570
2	4	5	33.251
2	5	3	37.012
2	5	4	15.474
2	5	5	17.905
3	1	4	58.322
3	1	6	30.689
3	2	4	6.971
3	4	3	10.785
3	4	4	36.888
3	5	5	30.862
3-4	4	5	49.457
4	1	1	58.633
4	1	2	26.682
4	1	4	41.366
4	1	5	13.513
4	1	6	31.728
4	2	1	2.310
4	2	3	3.888
4	4	5	61.036
5	1	3	9.340
5	1	4	41.954
5	1	5	48.565
5	1	6	75.779

Table 5. Phylakopi: sum of squared deviations of standardised bone frequencies by context.

been noted that the large bodies of muscle are situated on the proximal and posterior elements of the skeleton, whilst the best sources of marrow tend to be the anterior and distal elements. Much of this work has been carried out by Binford and reviewed by him in two books (Binford 1978 and 1981). In the first of these he developed a series of general utility indices by means of which he was able to characterise and interpret butchering strategies and the debris they produce.

Phase code	Mean sum of squares
0	45.601
1	27.833
2	27.321
3	29.086
4	29.782
5	43.815
1-2	31.097
3-4	49.457
Complex	
1	37.334
2	27.923
3	25.203
4	28.283
5	22.077
Type	
1	36.313
2	12.690
3	22.876
4	31.501
5	29.170
6	50.757
7	63.045

Table 6. *Phylakopi*: mean sum of squares (attrition index) by phase, complex and type.

The most general of these is the modified general utility index (MGUI). Although this index has been criticised (by Lyman 1985, for example) it has been used by Speth (1983) to very good effect. MGUI was employed as a general measure of utility for different skeletal elements at *Phylakopi*. The MGUI assigns a value between 1 and 100 to all elements of the ungulate skeleton on the basis of an assessment of general utility. In the original formulation, different MGUI values were assigned to the proximal and distal ends of long bones.

It was difficult to decide which part of the element was being described in all data records from *Phylakopi* because of inherent limitations in the coding scheme. However, a study of those cases where discrimination was possible showed that at *Phylakopi*, as on many other sites, one end of most long bones was consistently commoner than the other. For example, the distal humerus was consistently commoner than the proximal humerus, distal tibia was commoner than the proximal tibia and so on. It was also found that the less common end of these bones was seldom

recovered in isolation; one either got the whole humerus or the distal end, never the proximal end alone. MGUI indices for the commoner end were used in the present study. For example, Binford gives an MGUI of 43.47 for the proximal humerus and 36.52 for the distal humerus, so the value of 36.52 was used for all humeri. If this study was to be repeated from scratch, a more flexible and unambiguous coding scheme would be used.

### General utility at *Phylakopi*

We can now use the analytical device for bringing all assemblage subsets onto a common scale in conjunction Binford's General Utility measures to look at the *Phylakopi* data directly. The assemblage from each phase, each complex and each context type was standardised, species by species, in the manner described above. Standardised frequencies were exponentiated to bring them back onto a log-linear scale and a general utility statistic calculated for each subset as follows:

$$UTIL(j) = \sum_i A(i,j) * MGUI(i) \tag{8}$$

where  $A(i,j)$  is the standardised frequency of element  $i$  of assemblage subset  $j$ ,  $MGUI(i)$  is that element's MGUI and  $UTIL(j)$  is a measure of the relative utility of assemblage subset  $j$ . The results are presented in Table 4.

In general, the more common the species, the less variation in  $UTIL$  was manifested between assemblage subsets. The strongest and most coherent variation in  $UTIL$  was between context types. It seems from these figures that floors tend to produce assemblages of low utility whilst subsets derived from walls, footings, external contexts and between floors (types 1, 4 and 6) produce high utility assemblages, supporting the view that these were the loci in which domestic refuse was commonly dumped.

Two interesting observations have been made using Binford's utility measure. The bulk of the material recovered seems to have been produced by large scale refuse disposal and to be taphonomically and behaviourally uniform (as suggested by Gamble 1982). However, there are assemblage subsets which deviate from this general pattern and these tend to be the smaller subsets between floors, in the vicinity of walls and in 'external contexts'.

PHASE	COM.	TYPE	OVICAPRID			COW			PIG		
			SCALE	AGED	ZERO	SCALE	AGED	ZERO	SCALE	AGED	ZERO
0	3	5	8	4	10	0	0	16	2	0	12
0	2	6	108	36	2	8	4	11	8	6	9
0	2	1	93	28	3	2	1	14	8	6	8
1	2	1	35	17	4	2	1	14	8	5	10
1	2	2	14	6	13	0	0	16	0	0	14
1	2	4	81	47	3	2	2	15	18	11	5
1	2	5	10	4	9	1	0	15	1	1	13
2	1	1	70	24	4	33	15	4	15	9	8
2	5	1	8	5	12	0	0	16	0	0	14
2	1	2	1	0	16	2	0	14	1	0	13
2	2	3	134	56	1	32	7	5	24	12	3
2	5	3	40	21	4	7	5	12	2	1	12
2	2	5	9	3	12	0	0	16	0	0	14
2	3	5	33	23	8	4	2	12	6	1	10
2	4	5	39	6	3	7	6	11	10	6	8
2	5	5	12	3	9	4	1	13	4	2	11
2	2	4	20	12	5	1	1	15	2	2	12
2	5	4	14	9	7	1	0	15	2	1	12
2	1	4	3	2	14	0	0	16	1	1	13
2	1	7	178	79	1	27	5	5	21	7	3
3	4	3	8	3	12	0	0	16	2	0	12
3	1	6	15	5	9	16	1	10	10	3	8
3	1	4	169	91	2	67	23	1	30	14	4
3	2	4	6	4	13	0	0	16	0	0	14
3	4	4	54	21	1	14	5	7	13	6	6
3	5	5	33	11	6	2	0	14	1	0	13
4	1	1	107	47	1	10	3	8	28	10	5
4	2	1	2	0	15	0	0	16	0	0	14
4	1	6	33	14	5	0	0	16	8	2	7
4	1	4	63	23	2	22	7	6	15	8	5
4	1	5	4	1	15	2	1	14	7	1	11
4	4	5	92	36	2	10	5	11	16	7	7
4	1	2	23	13	8	0	0	16	6	4	11
4	2	3	2	0	15	0	0	16	1	1	13
5	1	4	56	21	2	5	0	12	6	2	9
5	1	3	4	1	15	0	0	16	4	3	12
5	1	6	142	45	2	7	3	11	41	14	3
5	1	5	72	24	2	26	8	6	16	9	7
3-4	4	5	83	35	1	14	4	7	12	6	8
1-2	3	4	36	7	2	1	1	15	1	0	13

Table 7. Phylakopi: species abundance data (COM. = Complex).

*Analysis 2: measuring survivability*

Although the factors that destroy animal bones may have many substantively different causes, it is the common observation of many archaeozoologists that they often have broadly similar effects on assemblage profile: bones which tend to survive, tend to survive. This is because two mechanical factors are determining a bone's resilience to destruction, its density and its

surface area to volume ratio. Spongy bones which fuse late (like proximal humerus for example) and flat, thin laminoid bones (like blade of scapula) are not well equipped to survive the effects of dogs, weather, trampling, etc.

We have already seen that the variance of the columns of A are related to the variances of the independent formation processes in a very simple way:

$$V(A) = V(B) + V(B1) + \dots \quad (9)$$

The greater the variance of A, the greater will have been the sum of the variances of the formation processes. Since formation processes (as defined here) destroy bones, the variances of these columns can be used as crude indices of the severity of bone attrition experienced during the taphonomic career of that assemblage. The variance is simply the mean of the squared standardised frequencies and the standard deviation is the square root of the variance, so these quantities can also be used as crude attrition indices too.

The assemblage was subdivided into 40 uniquely defined composite sets using the factors phase, complex and type. All bone frequencies were standardised together across species. The total sum of squares of the standardised frequencies of all elements of the skeleton was then calculated. They are presented in Table 5. These values can be averaged by phase, complex and type to give a crude attrition index (Table 6).

Phases 0 and 5 which Gamble (1982) indicated as having relatively few cattle also show evidence of high rates of attrition. It is possible the change in cattle abundance may be an artefact of differential preservation. Types 2 (floors) and 3 (pits), in which assemblages tend to be small, have relatively low attrition indices possibly indicating that these contexts are favourable for bone preservation. At Phylakopi, as on many Aegean Bronze Age sites, floors and pits are often associated. As floor surfaces become damaged they are often covered with a layer of fill, sometimes containing artefacts and bones, and the whole sealed to form a new floor surface. It is not surprising, therefore, that floors and pits produce low attrition indices.

We now have evidence to support a new interpretation of the Melos data. It is possible that Gamble's time-trend is an artefact of differential preservation. It is clearly necessary to undertake a direct examination of species representation which does not employ the standardisation procedure to see whether the pattern is sufficiently robust to emerge from an independent approach.

### Analysis 3: taxonomic variability

The same 40 uniquely defined composite units from the preceding study were re-employed.

<i>Eigenvalues</i>		
Eigenvalue	% of trace	Cumulative %
7.0579	78.42	78.42
1.0700	11.89	90.31

### *Variable loadings on the first two components*

Variable	Component 1	Component 2
S/G Total bones	0.3541	-0.2025
S/G Bones aged	0.3506	-0.0969
S/G Elements absent	-0.3072	0.3133
COW Total bones	0.3255	0.4648
COW Bones aged	0.3072	0.5174
COW Elements absent	-0.3334	-0.4277
PIG Total bones	0.3390	-0.2446
PIG Bones aged	0.3368	-0.2076
PIG Elements absent	-0.3427	0.2862

Table 8. Results of Principal Components Analysis on data in Table 7.

Each unit contained between 2 and 266 identified elements. For each of the three major species (ovicaprid, cow and pig) 3 variables were defined, these were:

- (1) Number of bones in assemblage subset.
- (2) Number of bones successfully aged in subset.
- (3) Number of skeletal elements absent altogether from the subset (i.e. the number of zero frequencies recorded).

The number of bones is probably the simplest (arguably 'crudest') indicators of scale available.

The number of bones successfully aged (i.e. the number for which fusion data was available) is, in addition to being an index of scale, also an index of 'goodness of preservation' as it only documents those bones which survive sufficiently well to permit supplementary data to be gathered. The third variable, the number of elements absent, was transformed onto a logarithmic scale, and is also considered as a 'dual purpose' variable, an index of assemblage scale and goodness of preservation. If preservation is good, LOG(number of zero frequencies) will be low and *vice versa*.

Phase	Complex	Type	Score
4	2	1	-2.6265
1	2	2	-2.5323
3	2	4	-2.4852
4	2	3	-2.4859
2	2	5	-2.4533
2	1	2	-2.4343
2	5	1	-2.4280
2	1	4	-2.3964
3	4	3	-2.2744
0	3	5	-2.1890
5	1	3	-2.1087
1	2	5	-2.1038
4	1	5	-1.8936
2	5	4	-1.8153
3	5	5	-1.6995
2	5	5	-1.5700
2	2	4	-1.4678
1-2	3	4	-1.3796
4	1	2	-1.3557
2	3	5	-0.8718
4	1	6	-0.8558
2	5	3	-0.6274
1	2	1	-0.5588
3	1	6	-0.5360
2	4	5	0.3065
0	2	1	0.3807
5	1	4	0.5319
0	2	6	1.1605
4	4	5	1.7081
1	2	4	1.7171
3	4	4	1.7209
3-4	4	5	1.8411
4	1	4	2.3750
5	1	5	2.4818
2	1	1	2.9926
4	1	1	3.1891
5	1	6	4.0654
2	1	7	4.9666
2	2	3	5.0191
3	1	4	8.6749

Table 9. Principal Components scores for Component 1 ('Scale').

Thus, evidence of variation in scale of the assemblage subsets would come in the form of strong, joint co-variation of all three variables of all three species, whilst evidence for variation in profile (expressed as changes in species abundance) would be in the form of low or negative co-variation between the indices of two or more of the three major species. For any one species, variables 1 and 2 will be positively correlated with each other and negatively correlated with 3.

Phase	Complex	Type	Score
5	1	6	-2.7668
1	2	4	-1.8671
4	1	1	-1.6703
0	2	1	-1.1060
5	1	4	-1.1048
2	1	7	-0.9232
4	1	6	-0.8036
4	4	5	-0.6878
2	2	3	-0.5481
1	2	1	-0.5316
0	2	6	-0.5292
4	1	2	-0.3602
3-4	4	5	-0.2683
1-2	4	4	-0.2333
3	4	4	-0.1767
2	2	4	-0.0514
2	5	4	0.0338
2	4	5	0.0965
3	5	5	0.1054
5	1	3	0.1368
0	3	5	0.1632
2	3	5	0.2260
3	4	3	0.2290
1	2	5	0.2329
2	5	5	0.3303
2	1	4	0.3344
2	5	1	0.3675
4	2	3	0.3707
2	2	5	0.3723
4	1	4	0.3762
4	1	5	0.3876
3	2	4	0.4072
1	2	2	0.4245
4	2	1	0.4899
3	1	6	0.5319
2	1	2	0.6175
2	5	3	0.6345
5	1	5	0.7252
2	1	1	2.4303
3	1	4	3.6050

Table 10. Principal Components scores for Component 2 ('Profile').

The raw data for all 40 uniquely defined subsets, before logarithmic transformation of the third variable, are shown in Table 7. Principal Components Analysis was used to clarify the inter-relationships between these variables. This analysis extracted two eigenvectors with eigenvalues explaining more than 10% of the variation described in the correlation matrix. The remaining seven eigenvalues each explained less than 4% of the variation characterised in the correlation matrix (see Table 8).

Classified by phase

Phase code	Mean 'scale'	Size of class
0	-0.2189	3
1	-0.8694	4
2	-0.2138	13
3	0.5668	6
4	-0.2398	8
5	1.2426	4
1-2	-1.3796	1
3-4	1.84111	1

Classified by complex

Complex	Mean 'scale'	Size of class
1 (Sanctuary)	1.1798	15
2 (NE Megaron)	-0.7008	12
3 (SW Megaron)	-1.4831	3
4 (S Megaron)	0.6604	5
5 (II S)	-1.6280	5

Classified by type

Type	Mean 'scale'	Size of class
1 (walls, etc.)	0.1582	6
2 (floors)	-2.1074	3
3 (pits)	-0.4091	5
4 (debris/refuse)	0.5475	10
5 (make-up/fill)	-0.5866	11
6 (external)	0.9585	4
7 (other)	4.9666	1

Table 11. Mean scores on Component 1 ('scale').

The first component, which accounts for 78% of the variation in the correlation matrix, satisfies the criteria suggested as indicating variation in scale. All the direct indicators of assemblage scale ('total bones', 'bones aged' and '-LOG(Elements absent)') are positively correlated with it.

The principal component scores may usefully be tabulated in ascending rank order, so that any obvious association between the three contextual variables and the scale and profile components may be seen (Tables 9 and 10). A visual comparison of the raw data (Table 7) with the scores of each subset is sufficient to

Classified by phase

Phase code	Mean 'scale'	Size of class
0	-0.4907	3
1	-1.7413	4
2	3.9204	13
3	4.7018	6
4	-1.8975	8
5	-3.0096	4
1-2	-0.2333	1
3-4	-0.2683	1

Classified by complex

Complex	Mean 'scale'	Size of class
1 (Sanctuary)	0.1011	15
2 (NE Megaron)	-0.1947	12
3 (SW Megaron)	0.0520	3
4 (S Megaron)	-0.1615	5
5 (II S)	0.2943	5

Classified by type

Type	Mean 'scale'	Size of class
1 (walls, etc.)	-0.0034	6
2 (floors)	0.2273	3
3 (pits)	0.1646	5
4 (debris/refuse)	0.1323	10
5 (make-up/fill)	0.1683	11
6 (external)	-0.8199	4
7 (other)	-0.9232	1

Table 12. Mean scores on Component 2 ('profile').

indicate a general agreement between a subset's score on Principal Component 1 and the relative quantity of bone recovered from that context.

To test this, each of the 40 subsets was given two ranks, one of which was the ranking of that subset on the first component and the other was its rank order of assemblage size (the total number of identified bones). Spearman's rank correlation coefficient was then calculated between these two ranked variables over all 40 subsets. Spearman's coefficient, like Pearson's R to which it is related, takes on a value of 1.0 for a perfect

positive correlation, -1.0 for a perfect negative correlation and 0.0 for no correlation. The value obtained was 0.959: strong evidence that Principal Component 1 represents assemblage scale.

Principal Component 2 satisfies the criteria suggested for recognising profile. This is a component on which the small artiodactyls (ovicaprid and PIG) have low negative loadings and the COW indices have moderate positive loadings. Thus assemblages with high positive scores on this component would be those in which cow were relatively abundant and ovicaprid and pig relatively scarce.

Thus a very simple pattern has emerged from this PCA in which the whole assemblage, on subdivision into contextually defined subunits, manifests only two major sources of variation. Since 78% of the variation in assemblage data was explained by the scale component, we must conclude that the bulk of the variation between assemblage subsets is attributable to scale and a much smaller proportion of the variation represents profile of assemblage. Variation in profile typically takes the form of shifts in the relative abundance of small and large artiodactyls. There is virtually no evidence for variation in the relative abundance of pigs and ovicaprids.

### **The effects of context on species representation**

The Principal Components Analysis just described treated the whole assemblage as an amorphous set of analytical units. Of course, this is not the case and the factors that allow us to partition the assemblage can be used to interpret the principal component scores. We begin by calculating a mean score on each of the two components for each unique value of phase, of context type and of trench complex. These mean scores are interpreted by remembering that a subset with a negative mean score on the first (scale) component may be said to be of small scale and vice versa, whilst a subset with a negative mean score on the second component must have comparatively few cattle bones and vice versa. The results of these calculations are presented in Tables 11 and 12.

Although there is no clear pattern in assemblage scale between phases, there is a tendency for the earlier phases (0-2) to produce subsets on a generally smaller scale

than the later. This is probably because a larger area of the later phases was stripped than of the earlier. Consequently, each context type was better represented in the former. Among the complexes there are certain obvious 'outliers'. The sanctuary complex is a notable instance because a large area was stripped around the sanctuary, producing larger assemblages. The South West Megaron complex consists of small soundings made into areas between free standing structures cleared by previous excavation. Probably as a consequence of this only small quantities of bones were recovered from each of the contextual units defined therein.

When we look at variation in scale between context types, we see that floors, pits, make-up and fill, which are quickly formed and sealed deposits produce smaller assemblages than those deposits formed by gradual accumulation.

Quite a dramatic variation in profile is manifested between the various phases of the site (Table 12). As observed by Gamble (1982), there appears to be an increase in the relative abundance of cows to a maximum in phase 3 after which the proportion of cow bones falls back to a little above its level in phase 0. The fact that this pattern shadows that established in Table 6, where attrition indices show relatively poor survival prospects in phases 0 and 5, is suggestive.

Variation between complexes is not as striking as that observed between phases. Furthermore, these results do not correlate as clearly with the corresponding data from Table 6, possibly because assemblages from complexes 4 and 5 are very much smaller than the rest. Complex 2 (II B & II C) contains virtually no material later than phase 2.

When we look at context types we see that exposed external contexts in which deposition rates are low seem on average to produce fewer cattle remains than those which are quickly filled and sealed. Context types 1, 6 and 7 also produced high attrition indices in Table 6, indicating poor preservation. Note that, whereas cow bones are generally well represented in make-up and fill (mean profile 0.1683), they are not well represented in trench complex 4 (II A). The bulk of the bone from this trench was, nonetheless, derived from two large fill deposits. These were unusual in that both were extremely well drained; one of these was described in the level notes provided by the excavator as 'mixed gritty

Phase	Poor	Medium	Good	Total
0	124	103	10	237
1	0	146	26	172
2	226	170	371	767
3	41	313	46	400
4	41	247	163	451
5	190	67	122	379
1-2	0	38	0	38
3-4	0	0	109	109
Total	622	1084	847	2553

Table 13. Number of bones recovered from each of the three preservation classes, subdivided by phase.

fill', and the other as an 'intensely rubbly fill apparently from the levelling of the Second City walls. More stone than earth!'. It seems likely that at least one, and possibly both, of these 'fills' should in fact have been categorised differently, perhaps included in the 'other' category (7).

### Cattle abundance: preservation or palaeoeconomy?

Analyses 2 and 3 have shown that attrition indices and cattle abundance appear to be negatively correlated between time phases and between context types. Although Gamble attributed the shifts in cattle representation to changes in the demand for animal traction, this correlation implies that differential preservation is a more likely explanation. Of course, it is possible that the correlation is spurious; a mere coincidence. This possibility could be tested in a number of ways and one of the most obvious is to see whether the bulk of the bones actually recovered came from those contexts in which attrition indices were high. If this is not the case, the negative correlation between profile and attrition index is almost certainly spurious. We can classify the seven contextual types into three subsets (Table 15) on the basis of the attrition indices in Table 6.

Table 7 can be used to obtain the bone yields from each of these preservation classes by phase (Table 13). Expressing these figures as percentages and re-tabulating gives Table 14. We can weight these three categories to reflect goodness of preservation by assigning poor preservation contexts a weight of 1.0, medium

Phase	Poor	Medium	Good	PRES
0	52.39	43.46	4.22	1.5
1	00.00	84.88	15.12	2.1
2	29.46	22.16	48.37	2.2
3	10.25	78.25	11.50	2.0
4	9.09	54.77	36.14	2.3
5	50.13	17.68	32.19	1.8
1-2	00.00	100.00	00.00	2.0
3-4	00.00	00.00	100.00	3.0

Table 14. Percentage of bones from three preservation classes and derived estimate of 'goodness of preservation' (PRES) by phase.

preservation contexts a weight of 2.0, and good preservation contexts a weight of 3.0. An index of goodness of preservation (PRES) can now be calculated using a weighted average. Thus in phase 0, 52% of the bones are from poor contexts, 43% from medium and 4 % from good contexts and a weighted mean is obtained using:

$$PRES = (1.0 \times 0.52) + (2.0 \times 0.43) + (3.0 \times 0.04) = 1.5$$

(10)

Table 14 shows that the PRES statistic varies as follows. Mean PRES rises to 2.1 in phase 1, to 2.2 in phase 2, falls back to 2.0 in phase 3, rises to 2.3 in phase 4 and falls back to 1.8 in phase 5. Clearly, the material from phase 0 and phase 5 not only contain fewer cow bones than the intermediate phases but a larger proportion of the bones were recovered from contexts uncongenial to bone survival. The pattern is clear; we tend to get more cattle bone in those phases and contexts where preservation is relatively good.

We cannot be absolutely certain that differential preservation is the *cause* of changes in cattle bone representation because it is possible that cattle bones were simply cleared away from open areas or were consumed and dumped separately from the smaller artiodactyls. The hypothesis that differential preservation was the cause of variability in cattle bone distribution could be tested further using attrition indices of the sort proposed by Maltby (1985) or direct estimators of survival



rates based on release-recapture methods (Fieller and Turner 1982; Winder 1993). These methods would require re-examination of the bone and the preparation of new data.

### Archaeozoological conclusions and prospects

Throughout the late 1960s and 70s we were encouraged (in my view wrongly) to think of bone assemblages as 'samples' which had been 'biased' by the formation processes acting on them. An extensive theoretical literature on faunal quantification followed from this which focused our attention on analytical problems without proposing an effective set of solutions. This in turn put many practitioners into a serious bind. If we accept the 'sample bias' paradigm, the rigorous analysis and interpretation of bone assemblages is an almost impossibly complex problem.

Among many practitioners, this view fostered a belief that the best we could do was to get large faunal samples and use counts and percentages (all measures of relative *scale*) to draw palaeoeconomic and behavioural conclusions. Large 'samples' do not eradicate so-called 'bias'. Indeed, the results presented above show that, at Phylakopi, larger samples seem to be more biased (i.e. have more evidence for differential preservation) than smaller ones.

The desire for a large sample has caused many archaeozoologists to 'lump' assemblages together as much as possible so as to get a viable sample. The resulting *unifactorial* analyses may well lead to a naive interpretation of observed patterning. It is relatively common, for example, to infer time-trends in assemblages from which all intra-phase variability has been expunged. The dangers of the unifactorial approach are widely acknowledged in the textbook literature on statistics (see, for example, Fienberg 1977) but seem to have been ignored in the archaeozoological and, indeed, the wider archaeological literature.

As we have seen at Phylakopi, the auto-correlation of intra-phase (or 'lateral') variation with inter-phase (or chronological) variation may well result in a spurious time-trend that can only be detected when the effects of both factors are considered *simultaneously*. Phylakopi is not an isolated case; a more recent study has characterised spurious time-

Preservation class	Type	Description
Poor	7	Other
	6	External
Medium	1	Walls
	4	Occupation debris/refuse
Good	5	Make-up and fill
	3	Pits
	2	Floors

Table 15. Preservation classes derived from attrition classes in Table 6.

trends in the data for bones from the Palaeolithic rock-shelter at Klithi (Winder, in prep.).

A rigorous, multifactorial approach to the interpretation of bone data is possible using relatively simple data transformations (like taking logs and subtracting means) before applying mainstream statistical methods. In this paper, I have restricted myself to the generation of weighted means and variances and these alone were sufficient to provide valuable new insights that could be tested with a PCA on a summary dataset and a rank correlation coefficient. The possibilities for future work of this sort are unbounded.

Suppose, for example, we had grounds to believe that an assemblage of bones was modified by dog-gnawing. We could take an assemblage produced by experimental studies of dog-gnawing and standardise it in the manner described above. This would give us a profile vector for a potential population that had only experienced dog-gnawing. By regressing the dog-gnawing vector on an archaeological profile vector, we could obtain a least-squares estimate of the proportion of variation in the assemblage that could be attributed to dog-gnawing. The residuals about this regression line would describe that portion of assemblage variability that was independent of the effects of dog gnawing (including some of the effects of human behaviour). Patterning among the residuals could be interpreted directly by inspection or by further regression steps.

Finally, we should note that the key to mounting a truly multifactorial analysis of animal bone data is the recognition that assemblage formation processes alter both the

scale and the profile of the potential population in a consistent and mathematically tractable way. We have been accustomed by twenty or more years of conventional wisdom to consider differences between the profiles of assemblages and potential populations as part of a 'problem' which we 'solve' by lumping assemblages and undertaking unifactorial analysis of variation in crude measures of assemblage scale (MNI, NISP, weight, etc.). In fact, the only evidence we have about the severity and nature of assemblage formation processes is written into the profile of the assemblage. Our best prospect of understanding these signals is to invert the traditional approach; to find intelligent ways of correcting for gross differences in scale before mounting a truly multifactorial investigation of assemblage profile.

### Acknowledgments

I am most grateful to Clive Gamble for allowing me to use his data as an analytical test-bed for the methods described in this paper. I also acknowledge a grant from the Science and Engineering Research Council (RF/8186) that allowed me to locate this work in a wider statistical context.

### References

- Behrensmeyer, A. and Hill, E. (eds.) (1980). *Fossils in the making*. Chicago: University Press.
- Binford, L. (1978). *Nunamiut ethnoarchaeology*. New York: Academic Press.
- Binford, L. (1981). *Bones: ancient men and modern myths*. New York: Academic Press.
- Fieller, N. R. J. and Turner, A. (1982). Number estimation in vertebrate samples. *Journal of Archaeological Science*, 9, 49-62.
- Fienberg, S. (1977). *The analysis of cross-classified categorical data*. Cambridge, Mass.: MIT Press.
- Gamble, C. (1982). Animal husbandry, population and urbanisation, pp. 161-8 in Renfrew, C. and Wagstaff, M. (eds.), *An island polity: the archaeology and exploitation of Melos*. Cambridge: University Press.
- Gamble, C. (1985). Formation processes and the animal bones from the sanctuary, pp. 479-88 in Renfrew, C., Mountjoy, P., French, E., Younger, J., Cherry, J., Daykin, A., Moody, J., Morgan, L., Bradford, N., MacFarlane, C., Torrence, R., Gamble, C. and Whitelaw, T., *The archaeology of cult; the sanctuary at Phylakopi*. London: Thames and Hudson.
- Lyman, R. (1985). Bone frequencies: differential transport, in situ destruction and the MGUI. *Journal of Archaeological Science* 12, 221-36.
- Maltby, M. (1985). Patterns in faunal assemblage variability, pp. 33-74 in Barker, G. and Gamble, C. (eds.), *Beyond domestication*. London: Academic Press.
- Speth, J. (1983). *Bison kills and bone counts*. Chicago: University Press.
- Winder, N. (1986). *Faunal analysis; studies in the analysis and interpretation of animal bones from large, multi-phase archaeological excavations*. Ph.D Thesis, University of Southampton.
- Winder, N. (1991). Interpreting a site: the case for a reassessment of the Knossos Neolithic. *Archaeological Review from Cambridge* 10(1), 37-52.
- Winder, N. (1993). Using modern bone assemblages to estimate ancient populations. *Circaea* 10(2) 63-8.
- Winder, N. (in press). The confounding of excavation method with spatio-temporal indicators. In G. Bailey (ed.), *Excavations at Klithi 1983-1988: Palaeolithic archaeology and landscapes in Epirus, Northwest Greece*. Cambridge: McDonald Institute for Archaeological Research.

Revised disk copy received: February 1995 (the Editors apologise for the delay in publication).

## Medieval and early post-medieval horse bones from Market Harborough, Leicestershire, England, U.K.

Ian L. Baxter

*Leicestershire Archaeological Unit, Museum Annex, 116 Humberstone Drive, Leicester LE5 0RD, U.K.*

### Summary

*Two assemblages of horse bones from Market Harborough—one medieval, the other post-medieval—are described in relation to the known historical background of the town and its place in the post-medieval horse trade.*

### Introduction

The town of Market Harborough is situated in the extreme south of the county of Leicestershire near the border with Northamptonshire. Market Harborough is first mentioned in documentary sources in the Pipe Roll of 1176-7 which records the Sheriff rendering eight-and-a-half marks from Great Bowden and seven marks from Hauerberga (OE *hæfera beorg*: 'the hill where oats grew'). At the time of the Norman Conquest the manorial centre was at Great Bowden, with Harborough merely part of the Great Bowden field system. The similar contributions recorded in the Pipe Roll suggest a rapid development of the town, which is assumed to be a planned creation because of its proximity to the River Welland crossing point on the Leicester-Northampton road. By 1179-80 it held a separate manor but without its own field system.

The foundation charter for a market has unfortunately not survived, but this was probably the reason for the town's creation. A Monday market is mentioned at Market Harborough in 1219. The surnames of merchants in a 1327 subsidy list suggest that the population was recruited from amongst the freemen of neighbouring towns. One hundred and thirty-three people, including fifteen craftsmen, fourteen artificers, five merchants and eight victuallers, are listed in the poll tax returns of 1381. A bridge crossing the River Welland is mentioned in the Close Rolls of 1228 but it is not known if a bridge existed prior to the town's inception. There is evidence to suggest changes in the course of the river between the Middle Ages and the present time, with the original course closer to

the Kettering Road [St Mary's Road] as it entered the town.

Until 1991 no controlled archaeological investigation had ever been undertaken in the town. Amongst early post-medieval buildings of particular interest is the Peacock Hotel, fronting St Mary's Road. During refurbishments in 1954-5, excavations beneath the floor revealed hearths and a pebbled surface associated with medieval pottery (Cooper, unpublished a, 3-5). A series of evaluation excavations were undertaken by Leicestershire Archaeological Unit at Market Harborough in the summer of 1991 prior to proposed redevelopment. More extensive excavations in selected areas followed in September 1991 and concentrated in the yard and car park area of the Peacock Hotel (Fig. 18). Archive reports and reports to the developers on these excavations and a full animal bone report are held by Leicestershire Archaeological Unit (Cooper, unpublished a and b; Baxter, unpublished). Amongst the more remarkable finds were significant deposits of horse bones in an excavated section of ditch F4031 in Trench 4 and pit F2031 in Trench 2 (Figs. 19 and 20). It is these remains which form the subject of the present paper.

### Animal bone from ditch F4031

Ditch F4031 extended across the width of Trench 4 on a NE-SW alignment (Fig. 20). It had a shallow U-shaped profile and was 2.00 m wide and 0.59 m deep. The primary fill [909] produced 12th/13th century pottery. Its secondary fill, from which most of the bone was recovered, contained an abundance of

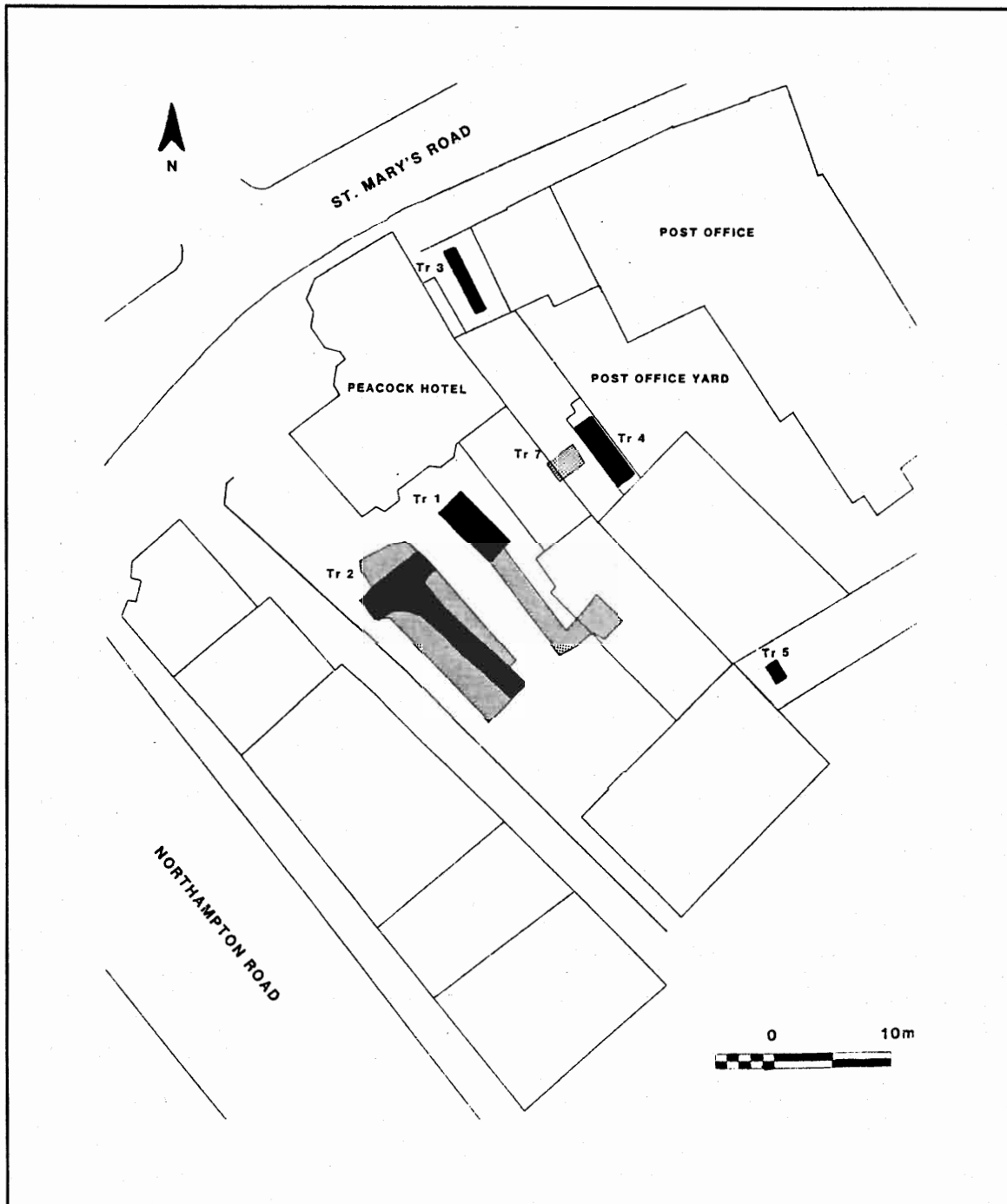


Figure 18. Location map for Trenches 1-5 and 7 (blocked areas indicate evaluation trenches).

12th/13th century pot together with two sherds of 16th century pot. These later sherds may have been intrusive, although an unidentified re-cutting of the ditch is possible. Ditch F4031 was cut into alluvial deposits of yellowish brown silty clay [913] and overlain by a mix of further alluvial and refuse deposits [907] that seem to have accumulated over a period of

several hundred years (Cooper, unpublished a, 10-11). Part of the same ditch was also found in Trench 7 (F7003), where pottery recovered from its fill suggested backfilling in the 13th/14th centuries. Only a small portion (1.00 x 0.60 x 0.30 m deep) was located, in the south eastern corner of the trench (Cooper, unpublished b, 15).

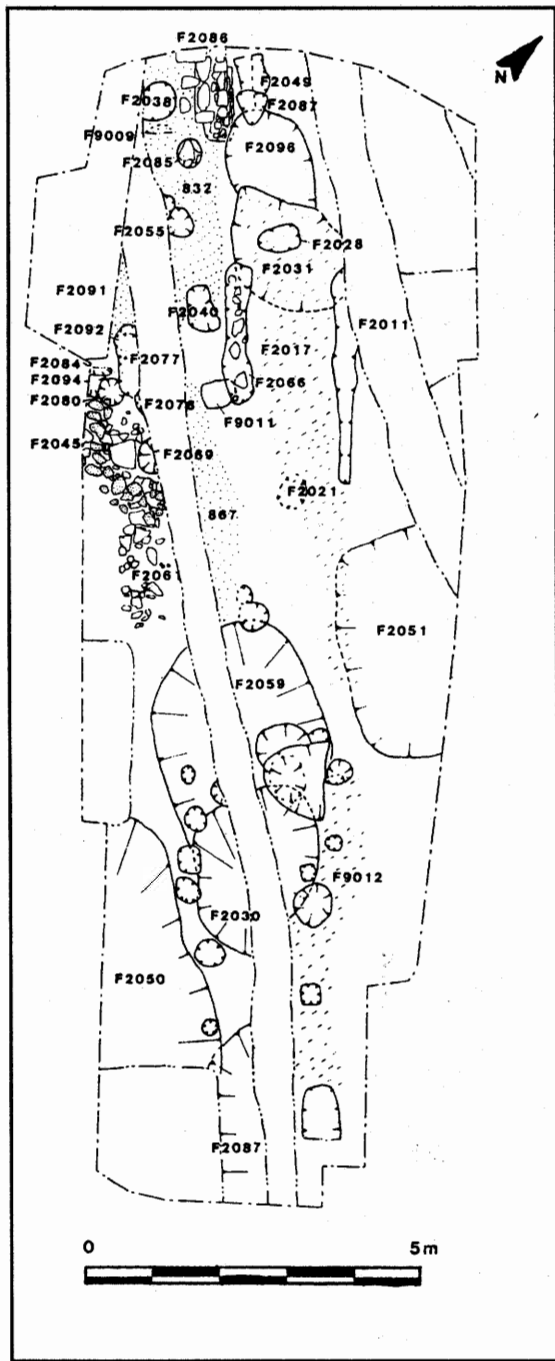


Figure 19. Trench 2 plan showing later medieval features.

Animal bone from F4031 was dominated by cattle fragments (over 68% of fragments identified to species) including 13 measurable horn cores and numerous horn core fragments. These were from predominantly adult and old adult animals and came from short-horned beasts (Armitage 1982). From the site as a whole, 70% of identifiable cattle fragments

Species	Feature		
	2031	4031	Total
Horse	89	28	117
Cattle	109	119	228
Sheep/Goat	21	18	39
Pig	7	7	14
Hedgehog	-	1	1
Crow	2	-	2
Fowl	1	-	1
Large mammal	37	5	42
Medium mammal	19	5	29
Indeterminate	166	118	284
<b>Total</b>	<b>451</b>	<b>301</b>	<b>757</b>

Table 16. Numbers of fragments per taxon (fused and articulating elements counted as 1).

Species	Feature		
	2031	4031	Total
Horse	8	3	11
Cattle	12	7	19
Sheep/Goat	2	1	3
Pig	2	1	3
Hedgehog	-	1	1
Crow	1	-	1
Fowl	1	-	1
<b>Total</b>	<b>26</b>	<b>13</b>	<b>39</b>

Table 17. Minimum Number of Individuals (based on the most numerous non-reproducible elements).

were from the cranial region (this includes a large number of frontal sinus fragments excluded from Table 18).

The sheep/goat bones from F4031 were mostly cranial and fore limb elements (Table 18).

Twenty-eight horse fragments were recovered from F4031 [908] representing 16% of identified bone and the second most numerous species. Fore-limb elements were twice as numerous as bones from any other region of the body (Table 18). No vertebrae, ribs or cranial elements attributable to horse were recovered from F4031, with the exception of one very worn lower 1st Molar from an old animal (cf. Levine 1982). One of the animals had an arthropathic condition of the hind leg in which the 3rd tarsal and metatarsal III were

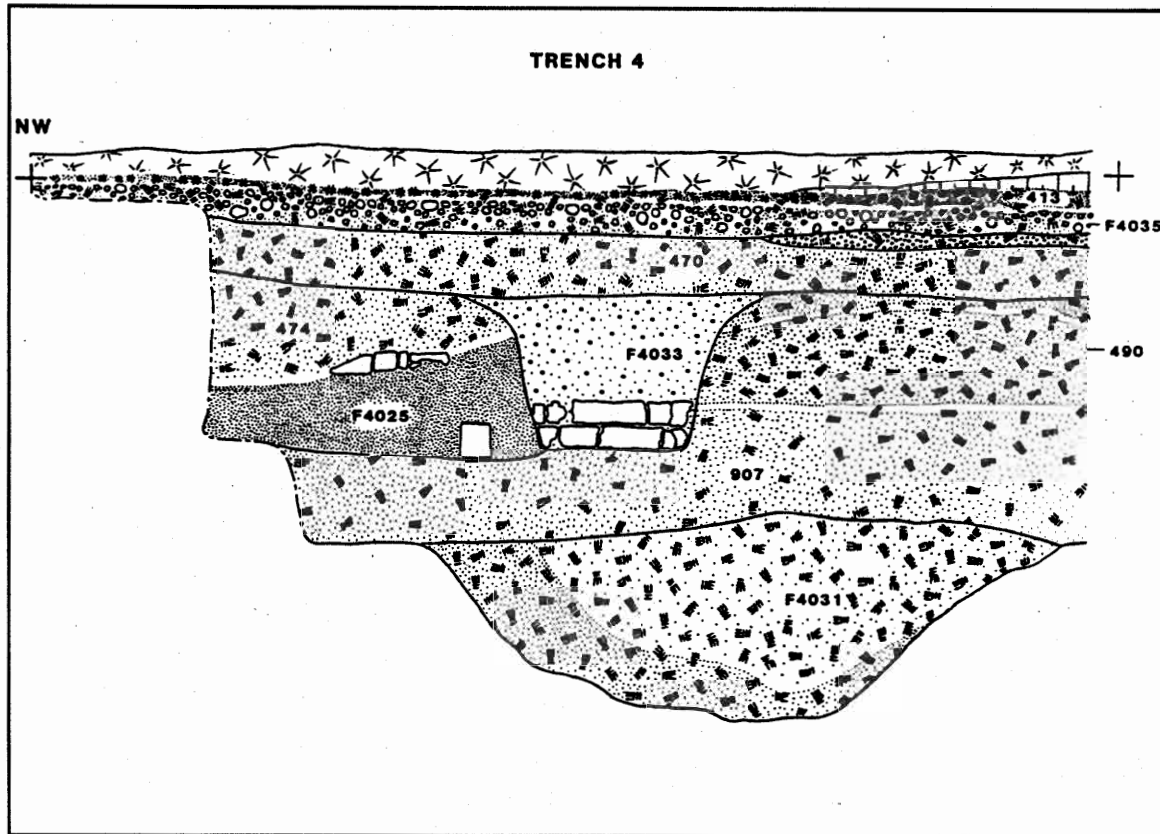


Figure 20. Trench 4 section.

Species and elements	F2031	F4031
<b>Horse</b>		
Cranium, maxilla, mandible	0.0	0.0
Vertebrae	0.0	0.0
Scapula, humerus, radius, ulna	13.8	17.7
Carpals	7.8	0.0
Mc II, III, IV	6.4	0.0
Pelvis, femur, patella, tibia	8.7	6.3
Calcaneum, astragalus, tarsals	14.7	1.3
Mt II, III, IV	8.3	3.8
Phalanx I, II, III	7.3	8.9
<b>Cattle</b>		
Horn core, cranium, maxilla, mandible	13.3	27.8
Vertebrae	0.5	0.0
Scapula, humerus, radius, ulna	3.2	5.1
Carpals	0.0	0.0
Metacarpus	0.0	0.0
Pelvis, femur, patella, tibia	4.6	3.8
Calcaneum, astragalus, tarsals	0.5	1.3
Metatarsus	0.5	2.5
Phalanx I, II, III	0.0	1.3

<b>Sheep/Goat</b>		
Horn core, cranium, maxilla, mandible	2.7	5.1
Vertebrae	0.5	0.0
Scapula, humerus, radius, ulna	3.7	6.3
Carpals	0.0	0.0
Metacarpus	0.0	2.5
Pelvis, femur, patella, tibia	3.7	2.5
Calcaneum, astragalus, tarsals	0.0	0.0
Metatarsus	0.0	0.0
Phalanx I, II, III	0.0	1.3

Table 18. Frequency of skeletal elements represented for main domestic species (%). (Excludes non-diagnostic frontal sinus fragments and isolated teeth.)

fused together with some new bone formation (exostosis). The joint surfaces are unaffected and this example is referable to spavin, a non-arthritic equine joint disorder affecting the hock (Baker and Brothwell 1980, 117-8). Two horse radius fragments have been trimmed by

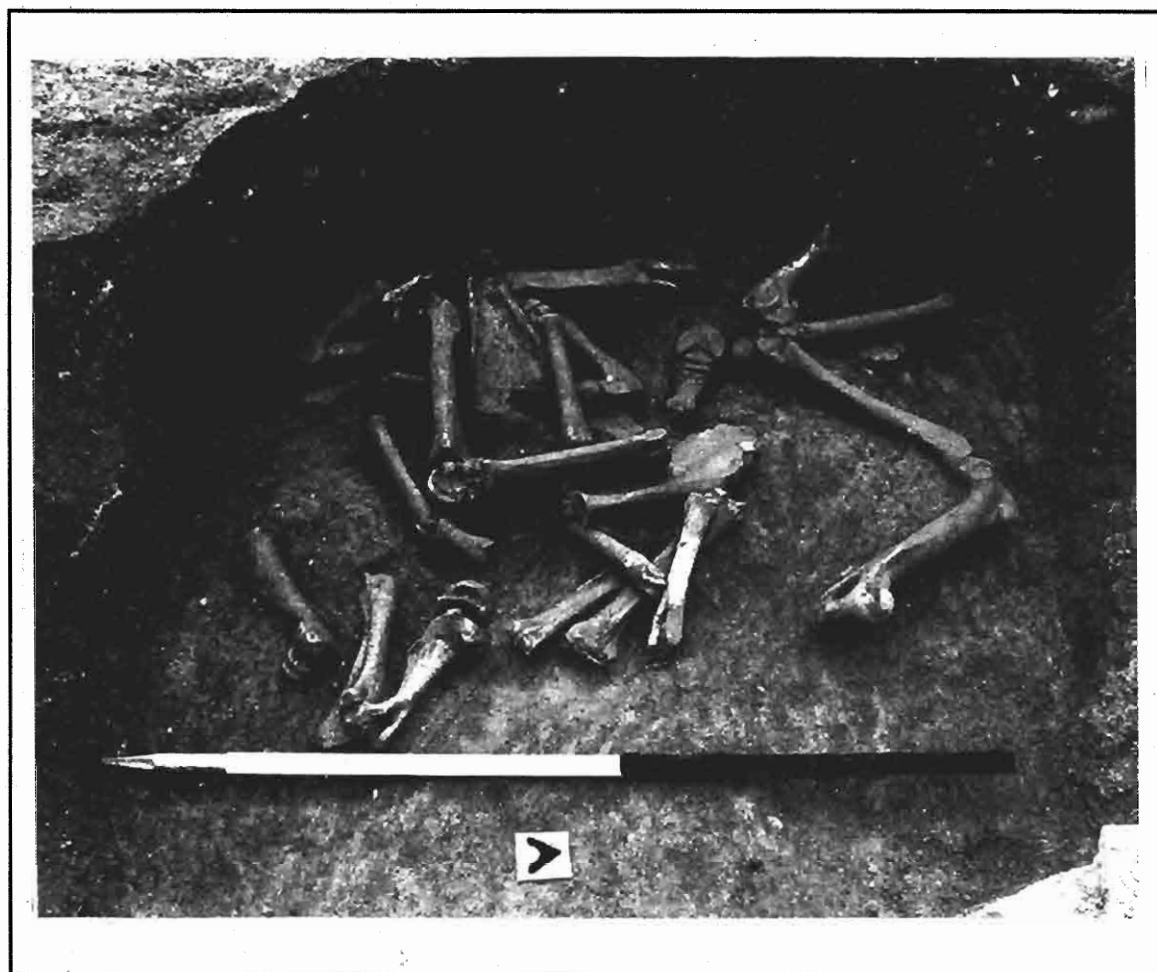


Figure 21. Pit F2031 with elements of horse and cattle limbs in anatomical relation.

Limb A: rt. hind leg	Limb C: lt. hind leg	Limb E: rt. fore leg	3rd carpal	Central tarsal	} f
Femur	Tibia	Metacarpal III	Metacarpal II	1st/2nd tarsal	
Tibia	Astragalus	Metacarpal IV	Metacarpal III	3rd tarsal	}
Calcaneum	Central tarsal	Phalanx I	Metacarpal IV	4th tarsal	
Astragalus	3rd tarsal	Phalanx III	Phalanx I	Metatarsal II	
Central tarsal	4th tarsal		Phalanx II	Metatarsal III	
3rd tarsal	Metatarsal III	Limb F: lt. fore leg	Distal sesamoid	Metatarsal IV	
4th tarsal		Humerus	Phalanx III	Phalanx I	
Metatarsal III	Limb D: hind leg	Radius+ulna		Phalanx II	
Metatarsal IV	Phalanx I	Radial carpal	Limb G: rt. hind leg	Distal sesamoid	
Limb B: rt. fore leg	Phalanx II	Intermediate carpal	Tibia	Phalanx III	
Humerus	Distal sesamoid	Ulnar carpal	Calcaneum		
Radius+ulna	Phalanx III	Accessory carpal	Astragalus		
		2nd carpal			

Table 19. Articulating horse skeletal elements from F2031; f—fused.

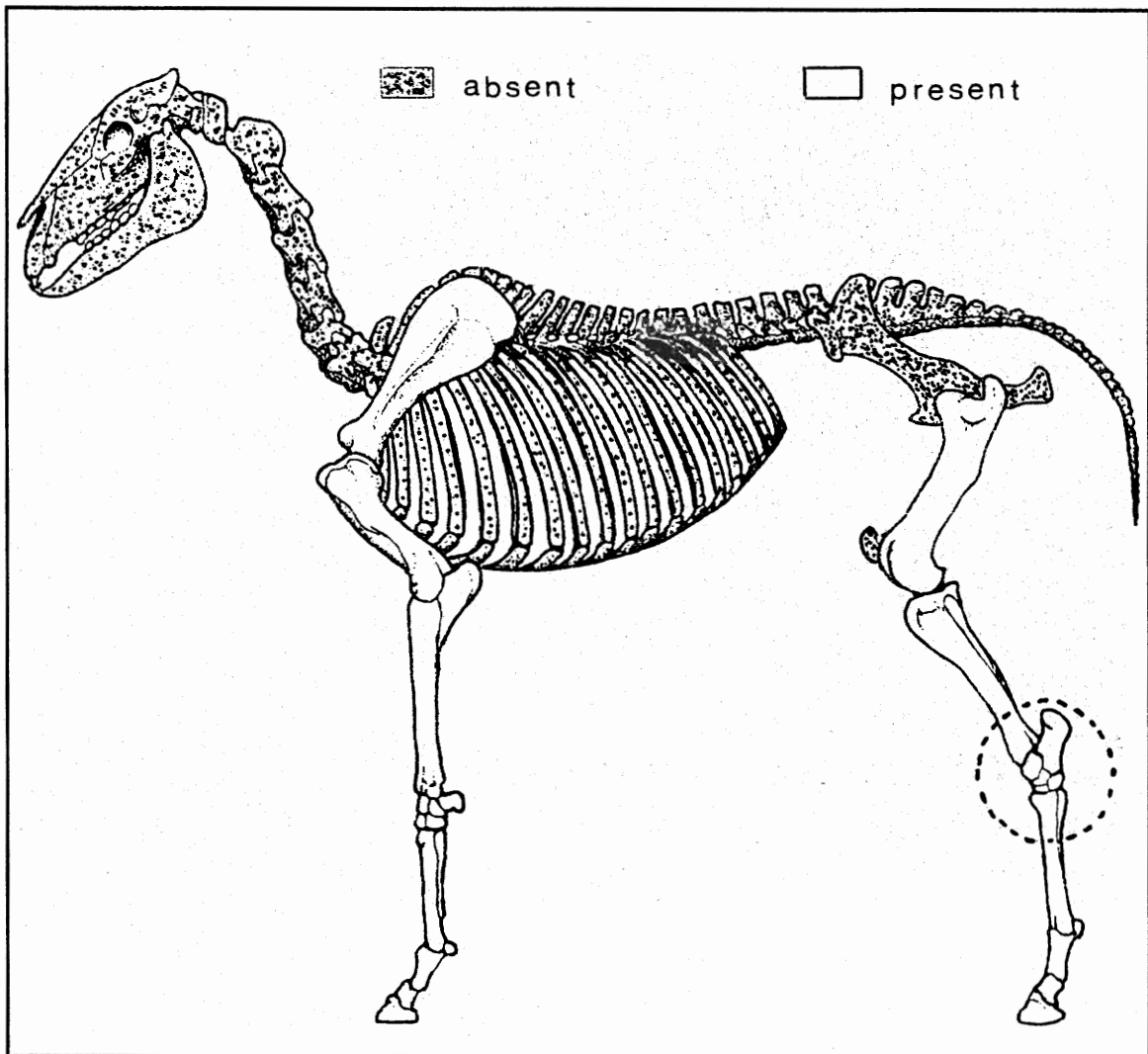


Figure 22. Horse skeletal elements from F2031. Circle indicates locus of arthropathic conditions.

(A) Articulating elements from F2031 [241]					
Limb	Skeletal element	GL (mm)	GLI (mm)	LI (mm)	Withers ht. (cm)
A	r Tibia	-	-	335	146.1
	r Mt III	277	-	270	143.9
B	r Humerus	-	298	-	145.0
	r Radius	354	-	338	146.7
C	l Mt III	279	-	268	142.8
E	r Mc III	231	-	221	141.7
F	l Radius	346	-	332	143.7
	l Mc III	233	-	224	143.6
G	r Mt III	273	-	264	140.7

Data for F2031 (n = 16): mean = 141.0; range: 131.7-146.7; SD = 3.97

(B) Isolated elements					
F/C	Skeletal element	GL (mm)	GLI (mm)	LI (mm)	Withers ht. (cm)
2031/241					
	l Radius	339	-	325	140.7
	l Radius	329	-	315	136.7
	r Mc III	226	-	217	139.1
	l Mc III	226	-	216	138.5
	r Tibia	334	-	302	131.7
	r Mt III	269	-	260	138.6
	l Mt III	266	-	257	137.0
4031/908					
	r Radius	325	-	312	135.4

Table 20. Horse withers heights (based on Kiesevalter 1888 in von den Driesch and Boessneck 1974); F/C—feature/context.



multiple light chops removing the distal ulna and opening the distal anterior shaft (Fig. 26). Both are highly polished and seem to have been used as implements of some kind, possibly wedges (G. C. Morgan, pers. comm.). Only one horse bone had been obviously butchered, a left distal humerus showing transverse cut marks on the medial condyle and a vertical cut mark next to the lateral condyle.

### Animal bone from pit F2031

Pit F2031 situated in the car park area of the Peacock Hotel in Trench 2 was completely excavated (Fig. 19). This was sub-square in plan, measuring 1.60 x 1.60 x 0.45 m in depth and contained a single fill [241]. Pottery from [241] was mainly of 13th/14th century date, though a small number of 15th/16th century sherds were also recovered. A 14th century copper alloy belt buckle of 'Jews Harp' type was also found in the fill of the pit which is probably best dated to the late 15th/early 16th centuries (Cooper, unpublished b, 12).

As with ditch F4031, cattle fragments were the largest component of the animal bones in the fill of pit F2031 (over 47%). Similarly, head elements predominated, followed by elements from both fore- and hind legs (Table 18). A total of 16 measurable horn cores together with a number of horn core fragments were recovered. The horn cores from F2031 were from short-horned beasts, but differ from the F4031 assemblage in containing a much higher proportion of young adult and sub-adult animals including a frontal fragment with a horn core bud (Baxter, unpublished).

At the base of pit F2031, amongst the articulating elements of from five to seven horse legs, were found the fore- and hind limb elements of at least one small bovine. These comprised a left humerus and articulating radius+ulna and a right femur and articulating tibia. Calculations based on the multiplication factors of Matolcsi (cited by von den Driesch and Boessneck 1974) give withers heights of 104.5 cm and 107.6 cm from the radius and tibia respectively. Apart from some peripheral dog gnawing, these four bones are complete and show no signs of butchery.

The sheep/goat and pig bones from F2031 were unremarkable and, together with the single bone of domestic fowl, seem to be domestic food refuse. The corvid bones consisted of a right coracoid and humerus from a single

individual. The humerus had tooth puncture marks at its distal end, characteristic of a cat. From their size, these bones could belong to either carrion crow (*Corvus corone* L.) or rook (*C. frugilegus* L.). Soil samples taken from [241] produced a few more sheep/goat fragments (including a what may have been a goat horn core fragment), a frog or toad tibio-fibula, five phalanges probably belonging to domestic dog and eleven fragments of dog coprolite containing bone fragments (Baxter, unpublished). Bone from the samples is not included in Tables 16-18.

Horse fragments made up 39% of the bones recovered from F2031, and included sixteen complete long-bones, over half of which came from the articulating elements of between five and seven legs (Tables 16 and 20). Whole limbs seem to have been mostly deposited at the bottom of the pit. It was not possible at the time to relate any of the scapulae to particular limbs, but in at least some cases these were certainly attached at the time of deposition. The only butchery noted was a depression, probably the result of a heavy blow with a blunt instrument, on a proximal humerus fragment just below the articulation on the medial side (Limb B), and a radius shaft fragment with multiple light chop marks on the posterior surface resembling those on the implements from ditch F4031 mentioned previously. Canid gnaw marks were far more frequent and on the complete limbs occurred particularly on projecting areas of ligament attachment, such as the ulna olecranon, femur trochanter major, and calcaneum tuber calcis.

A minimum number of eight horses was represented in the fill of pit F2031 (based on left scapula fragments) and at least five limbs were articulated when deposited (Tables 17 and 19). Apart from one very worn lower 3rd molar, no skeletal elements from the head, vertebral column, pelvis or ribcage were found in F2031 (Fig. 22).

### Age and size of the horses

As noted above, the only teeth recovered from both F4031 and F2031 belonged to aged animals and all of the limb bones had fused epiphyses. About half of the animals represented were afflicted with arthropathic joint disorders affecting the hock joint of the hind leg associated with heavy work and advanced age (see below). The horses represented in these deposits were adult and old adult animals.

**Humerus**

Feature/context	side	GL	GLI	GLC	Bp	SD	BT	DT	Bd
2031/241	r	-	298.0	287.0	-	34.0	74.0	35.0	79.0
	l	-	-	-	-	34.0	78.0	40.0	82.0
	l	-	-	-	-	-	73.0	34.0	80.0
	l	-	-	-	-	32.0	70.0	34.0	72.0
	r	-	-	262.0	-	30.0	69.0	34.0	71.0
	l	-	-	-	-	37.0	76.0	39.0	79.0
	l	-	-	270.0	-	34.0	69.0	36.0	79.0
	l	-	-	-	84.0	-	-	-	-

**Radius**

Feature/context	side	GL	LI	BFp	Bp	SD	CD	Bd
2031/241	r	354.0	338.0	74.0	82.0	39.0	115.0	74.0
	l	346.0	332.0	79.0	84.5	39.0	115.0	78.0
	l	339.0	325.0	72.5	79.5	38.0	115.0	77.0
	l	329.0	315.0	-	77.0	37.0	110.0	73.0
	l	-	-	-	-	-	-	72.5
4031/908	r	325.0	312.0	70.0	79.0	38.0	105.0	73.5

**Radius and ulna**

**Ulna**

Feature/context	side	GLI	Feature/context	side	LO
2031/241	l	402.0	2031/241	l	79.0

**Carpals**

Feature/context	side	GB radial carpal	GB 3rd carpal
2031/241	l	42.0	44.0
	l	42.0	44.0

**Metacarpal III**

Feature/context	side	GL	LI	Bp	SD	Bd
2031/241	r	231.0	221.0	50.0	33.0	48.0
	l	233.0	224.0	52.0	33.0	51.0
	l	226.0	217.0	52.0	33.0	48.5
	r	226.0	216.0	-	-	50.0
	l	-	-	44.0	30.0	-

**Femur**

Feature/context	side	GL	GLC	Bp	SD	CD	Bd
2031/241	r	-	357.0	-	41.0	150.0	92.0
	r	-	334.0	-	39.0	135.0	-

Table 21 (above, opposite and page 74). Equine measurements (based on von den Driesch 1974).

**Tibia**

Feature/context	side	GL	LI	Bp	SD	CD	Bd
2031/241	r	-	335.0	-	41.0	125.0	73.0
	l	-	-	-	43.0	125.0	80.0
	r	-	-	-	41.0	120.0	73.0
	r	-	-	-	38.0	115.0	74.0
	r	334.0	302.0	-	37.0	110.0	71.0

**Calcaneum**

Feature/context	side	GL	GB
2031/241	r	-	51.0

**Astragalus**

Feature/context	side	GB	GH	LmT	BFd
2031/241	r	60.0	55.0	56.5	47.0
	l	63.0	61.0	64.0	53.0
	r	65.0	59.0	56.0	50.0
	r	61.0	60.0	62.0	50.0

**Tarsals**

Feature/context	side	GB Central tarsal	GB 3rd tarsal	GB 4th tarsal
2031/241	r	49.0	47.0	31.0
	l	53.0	49.0	38.0
	r	-	-	37.0

**Metatarsal III**

Feature/context	side	GL	LI	Bp	SD	CD	Bd
2031/241	r	277.0	270.0	46.0	31.0	102.0	49.0
	l	279.0	268.0	53.0	32.0	100.0	49.0
	r	273.0	264.0	50.0	30.0	100.0	47.5
	r	269.0	260.0	48.0	29.0	100.0	-
	r	-	-	-	29.0	95.0	45.5
	l	266.0	257.0	-	32.0	95.0	49.0
4031/908	r	-	-	-	27.0	90.0	-
	l	-	-	47.0	25.0	85.0	-

**Phalanx I**

Feature/context	GL	Bp	SD	Bd
2031/241	83.0	52.0	38.0	53.0
	89.0	54.0	33.0	46.0
	89.0	58.0	36.0	52.0
	81.0	51.5	35.0	49.0
	-	59.0	35.5	-
	86.0	54.0	35.0	47.0
	77.0	51.0	35.5	44.0
4031/908	83.0	55.5	34.0	-
	86.0	56.5	35.0	49.5

Phalanx II					Distal sesamoid	
Feature/context	GL	Bp	SD	Bd	Feature/context	GB
2031/241	49.0	55.0	46.0	50.0	2031/241	52.3
	48.0	55.0	47.0	52.0		50.0
	49.0	54.0	43.0	47.0		47.0

Phalanx III				
Feature/context	GL	GB	Ld	HP
2031/241	71.0	78.0	56.5	43.0
	68.0	80.0	-	-
	-	-	55.5	42.0
	62.0	75.0	52.0	39.0

Withers heights of the horses represented in F2031 range between 131.7 cm and 146.7 cm with a mean of 141.0 cm or 14 hands (Table 20). The more limited evidence from measurable bones in F4031 indicates animals smaller, on average, than those represented in pit F2031 (Tables 20 and 21). The mean height for the F2031 horses is identical to that for the 18th century horse bones from Witney Palace in Oxfordshire (Wilson and Edwards 1993, 48). Most of the horses from F2031 are at the top of the height-range for medieval horses (Clutton-Brock 1992, 124) and would have been of a size acceptable to the 1537 Act of Henry VIII which sought to improve the quality of English horses (Chivers 1976, 7). If male, they would have been too small to comply with the later Act of 1541 which sought to limit the size of stallions to 15 hands and over in most counties including Leicestershire (*ibid.*, 8). The sex of the horses from the yard of the Peacock Hotel, however, is unknown.

### Pathologies

As noted above, a case of spavin from F4031 is represented by ankylosed tarsals and metatarsals. In addition, four hock joints from F2031 had ankylosed elements of varying severity (Figs. 22-5). In one case all the tarsals and metatarsals of the right hind leg were fused together to form a jack spavin (Fig. 25, above). Two other legs both had the central, 1st/2nd and 3rd tarsals fused (Fig. 25, below). A left hock joint had the calcaneum, astragalus, tarsals and metatarsals fused together with considerable pitting of joint surfaces and exostoses (Figs. 23-4). In this case the condition is infective arthritis.

Spavin is principally a disease of the tarsus of the horse, affecting the small bones of the inner lower aspect of the joint and causing exostoses which limit its movement. Spavin is not an osteo-arthritic condition and the joint surfaces are relatively unaffected. The causes are believed to include hereditary factors, inflammation of soft tissue resulting in fibrosis and new bone formation, and severe concussion possibly resulting from faulty conformation, faulty shoeing, heavy work, or working on hard surfaces (Baker and Brothwell 1980, 117-8). Spavin is also documented in recent and archaeological draught cattle (*ibid.* 117, 119).

Infective arthritis, resulting in pitting of the joint surfaces, ankylosis and exostoses of variable extent, is relatively unusual in modern horses, where the causal agent is often *Brucella abortus* which causes infectious abortion in cattle and a severe undulant fever infection in man (Baker and Brothwell 1980, 125). Brucellosis was apparently already present in medieval England (Trow-Smith 1957, 129-30). No evidence of 'ring bone' or of navicular disease was present in the foot elements found in either F4031 or F2031.

The horses with joint disorders would have been fit for slow work once the joint had ankylosed and were presumably worked until they were no longer profitable. Of course, lame mares or entire horses could still be used for breeding purposes as noted by Henry Best in 1641 (cited in Edwards 1988, 31-2). Horses in England were not well treated in the medieval and early post-medieval periods, being worked too strenuously too early in their lives and fed largely on grass. This undoubtedly contributed to their relatively

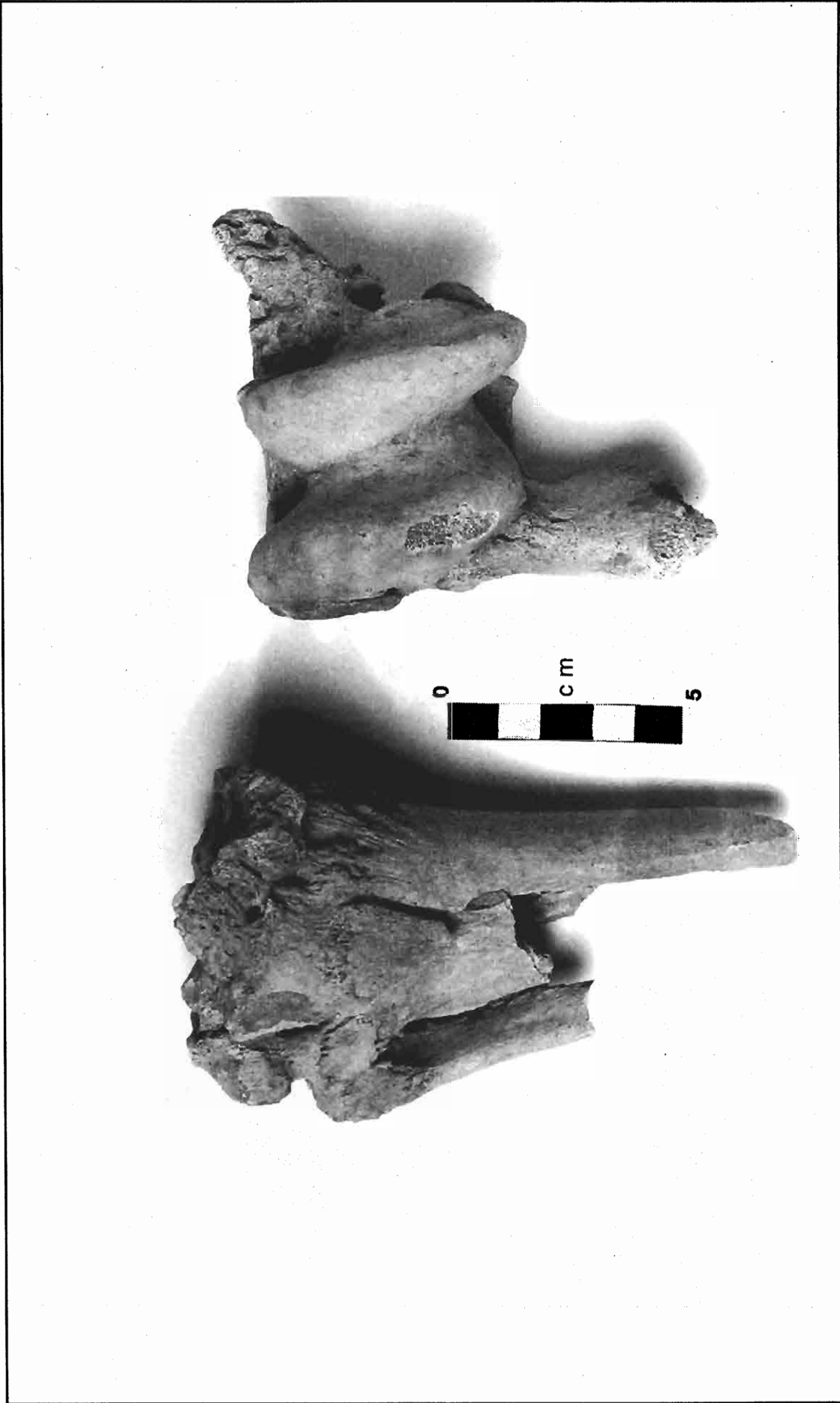


Figure 23. Fused hock joint from F2031 with infective arthritis: outer aspect.

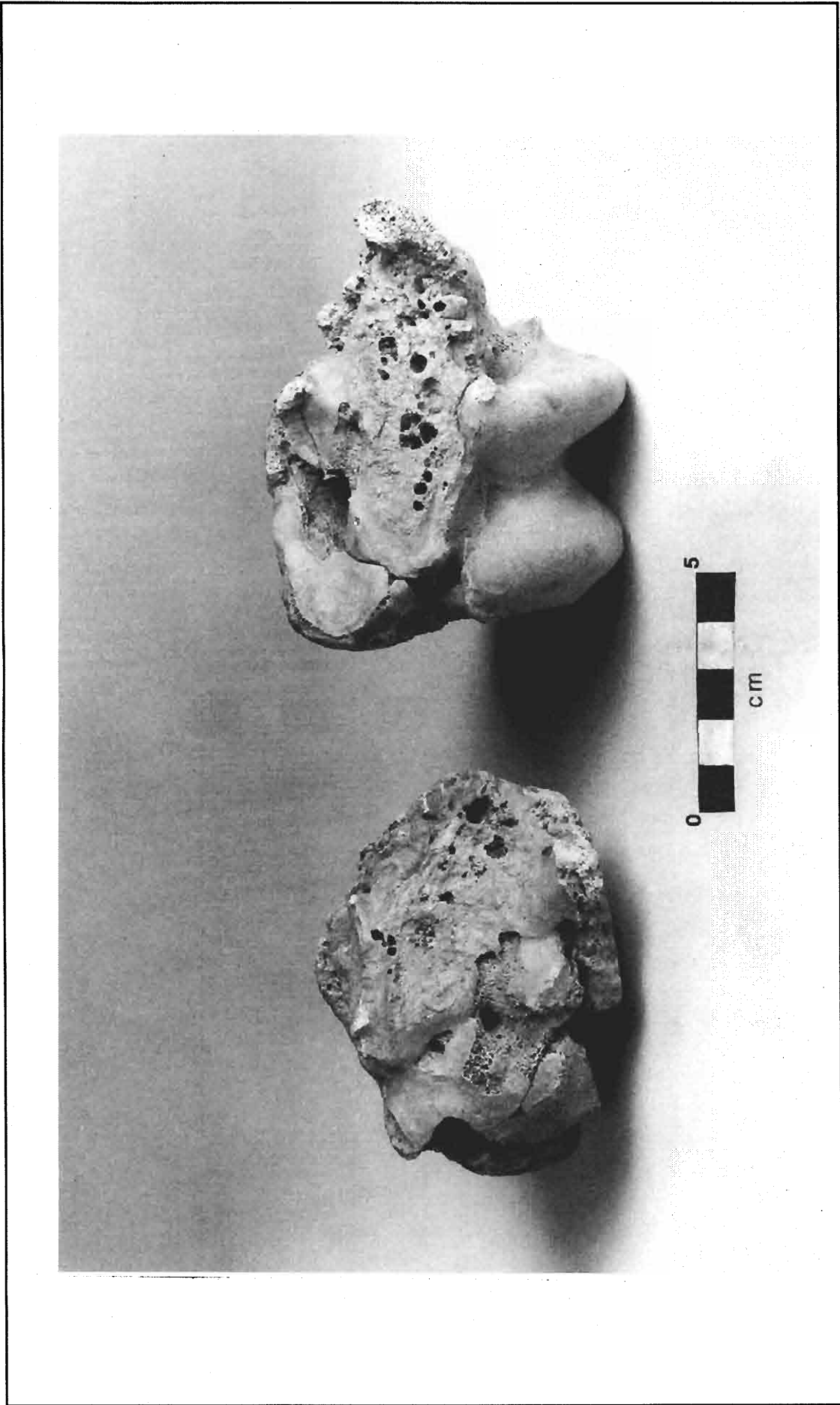


Figure 24. Fused hock joint from F2031 with infective arthritis: joint surfaces.



Figure 25. Spavin in bones from F2031: a fused metatarsal and tarsals (above) and fused tarsals.

small size and inferior performance compared with continental horses (Edwards 1988, 39).

### Discussion

Regional parallels for urban accumulations of horse bones can be found from two sites in Bedford (Grant 1979; 1983). In both cases large numbers of cattle horn cores were also found in the same deposits. An early medieval assemblage of 300 horse bones from at least nine animals found in pit F34 at St John's Street, Bedford contained no cranial elements apart from four loose teeth, no phalanges, and only one metapodial. The other limb bones

were all well represented, along with carpals, tarsals, patellae and many vertebral and rib fragments. The horse bones showed few butchery marks on them in contrast to the bones of other domestic animals at the site, suggesting that the carcasses were dismembered for easier disposal rather than for the removal of meat (Grant 1979, 105).

The similarities between the deposit in F2031 and the larger Bedford assemblage are striking and they undoubtedly originated from the operation of similar industrial processes. As Wilson and Edwards (1993, 50) have observed, the activities of specialist horse knackers are not well documented in the medieval and

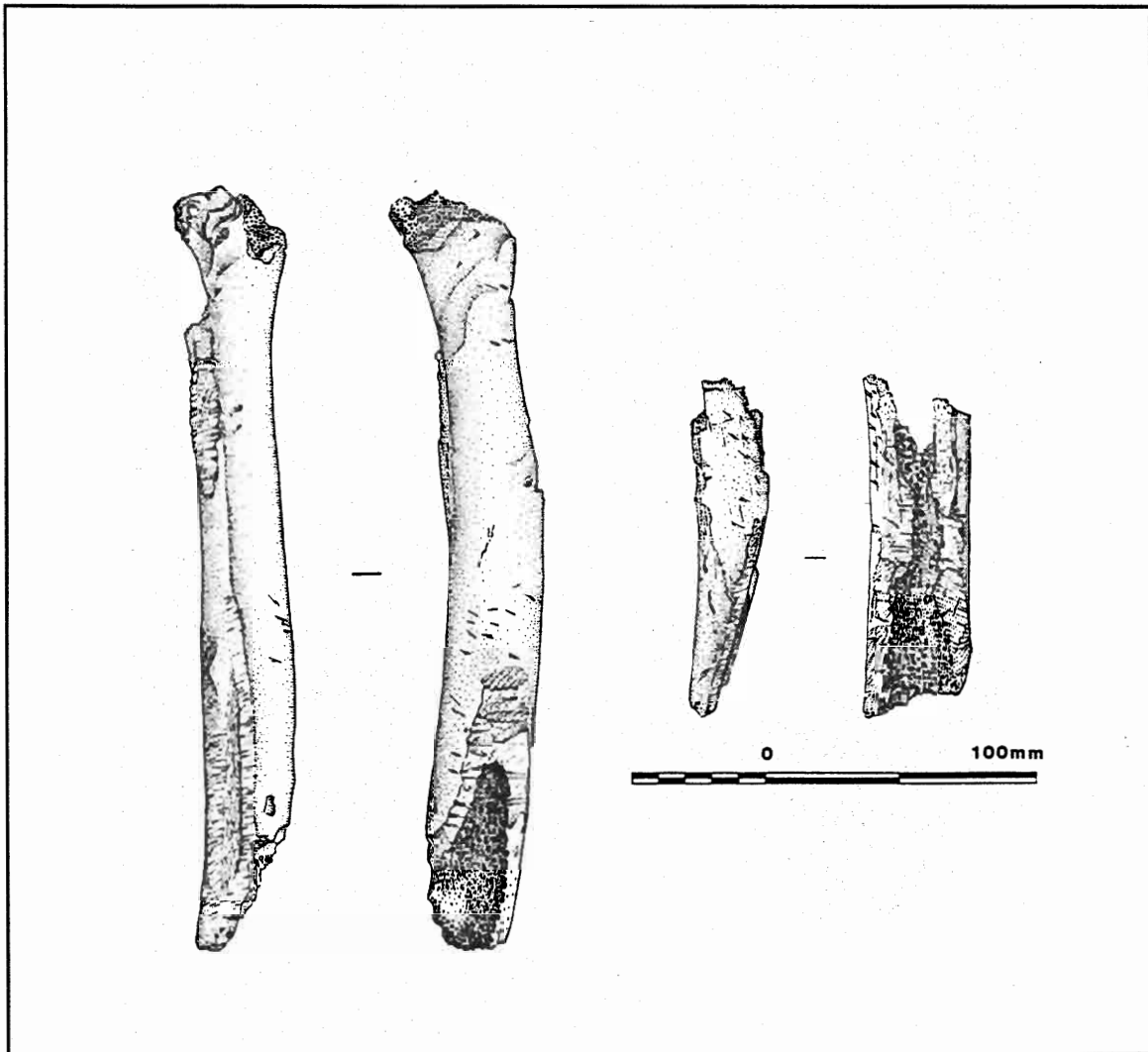


Figure 26. Bone implements from ditch F4031.

earlier post-medieval periods, especially in small towns. The Peacock Hotel site, very near to the probable earlier course of the River Welland, would have been well situated as a locus of the more offensive industrial processes concerned with animal products such as tanning and hornworking. The animal bones from ditch F4031 and pit F2031 would suggest that activities of this sort had a long history in the area.

It is not possible to determine the exact nature of the work to which the horses from the Peacock Hotel yard were put when alive. Horses were used as mounts, pack animals and for draught purposes to pull ploughs, harrows and carts. In Leicestershire the substitution of horses for oxen as a means of draught and traction is discernible in the

1530s and seems to be linked to the growth in the acreage of oats. With the reduction in common land, farmers in the late 16th and early 17th centuries found it necessary to buy in young stock in order to make the best use of their grazing rights (Edwards 1988, 5). By the 1720s, Leicestershire had become the foremost rearing area in the country for horses bred elsewhere, especially those destined for use as coach and dray horses (*ibid.* 35).

In the 17th century, the Duke of Newcastle considered that the East Midlands fairs, and particularly those at Market Harborough and Melton Mowbray in Leicestershire and Northampton and Rothwell in Northamptonshire, were the best for the purchase of good draught horses (*ibid.* 39).



## Conclusions

The accumulation of horse bones and cattle horn cores in ditch F4031, dating from the 13th century, and pit F2031, dating from the late medieval/early post-medieval period, at Market Harborough, suggest a long history of industrial activity concerned with animal products in the vicinity of the Peacock Hotel in close proximity to the River Welland. They seem to have been primarily concerned with the production of leather from the hides of cattle and horses and possibly with horn working. The average size of the horses shows signs of increase during this period and the numerous arthropathic conditions to which these animals were subject suggests that they were primarily draught animals. The production of draught horses for the whole of England and particularly London later became centred in Leicestershire with Market Harborough as one of the chief distribution centres.

## Acknowledgements

The author would like to thank Lynden Cooper for his assistance with the historical and stratigraphical background and for his permission to reproduce Figures 18-20, David Hopkins for his drawing of the bone implements in Figure 26, and Dr Graham Morgan of the University of Leicester for his observations regarding the same.

## References

- Armitage, P. L. (1982). *A system for ageing and sexing the horn cores of cattle from British post-medieval sites (17th to Early 18th century) with special reference to unimproved British Longhorn cattle*, pp. 37-54 in Wilson, R., Grigson, C. and Payne, S. (eds.) *Ageing and sexing animal bones from archaeological sites. British Archaeological Reports (British Series) 109*. Oxford.
- Baker, J. and Brothwell, D. (1980). *Animal diseases in archaeology*. London: Academic Press.
- Baxter, I. L. (unpublished). A44.1991 Peacock Hotel Car Park, Market Harborough. Report on the animal bones.
- Chivers, K. (1976, reprinted 1988). *The shire horse. A history of the breed, the society and the men*. London: J. A. Allen.
- Clutton-Brock, J. (1992). *Horse power. A history of the horse and the donkey in human societies*. London: Natural History Museum Publications.
- Cooper, L. (unpublished a). An archaeological evaluation in Market Harborough 1991: St Mary's Road and the cattle market. Report to developer. Leicestershire Archaeological Unit. Leicestershire County Council.
- Cooper, L. (unpublished b). Archaeological excavations in Market Harborough 1991: the Peacock Hotel yard, St Mary's Road. Report to developer. Leicestershire Archaeological Unit. Leicestershire County Council.
- Edwards, P. (1988). *The horse trade of Tudor and Stuart England*. Cambridge: University Press.
- Grant, A. (1979). *The animal bones*, pp. 103-7 in Hassall, J., St John's Street. *Bedfordshire Archaeological Journal 13*.
- Grant, A. (1984). *Medieval animal husbandry: the archaeozoological evidence*, pp. 179-85 in Grigson, C. and Clutton-Brock, J. (eds.), *Animals and archaeology: 4 Husbandry in Europe. British Archaeological Reports (International Series) 227*. Oxford.
- Levine, M. A. (1982). *The use of crown height measurements and eruption-wear sequences to age horse teeth*, pp. 223-50 in Wilson, B., Grigson, C. and Payne, S. (eds.), *Ageing and sexing animal bones from archaeological sites. British Archaeological Reports (British Series) 109*. Oxford.
- Trow-Smith, R. (1957). *A history of British livestock husbandry to 1700*. London: Routledge and Kegan Paul.
- von den Driesch, A. (1976). A guide to the measurement of animal bones from archaeological sites. *Peabody Museum Bulletin 1*. Harvard.
- von den Driesch, A. and Boessneck, J. (1974). Kritische Anmerkungen zur Widerristhöhenberechnung aus Langenmassen vor- und frühgeschichtlicher Tierknochen. *Säugetierkundliche Mitteilungen 22*, 325-48.
- Wilson, B. and Edwards, P. (1993). Butchery of horse and dog at Witney Palace, Oxfordshire, and the knacker and feeding of meat to hounds during the post-medieval period. *Post-Medieval Archaeology 27*, 43-56.

Revised disk copy received: December 1994 (the Editors apologise for the delay in publication).

## SHORT CONTRIBUTION

### *Unusual tooth wear on a late medieval horse skull from St Albans, Hertfordshire, U.K.*

**Alison Locker**, 15 Clifton Hill, Winchester, Hampshire SO22 5BL, U.K.

Two large late 14th/early 15th century pits were excavated at Belmont Hill, St Albans, Hertfordshire, by Chris Saunders of Verulamium Museum in 1980 and 1982. The animal remains in the pit fills were largely horse (at least 12 individuals) which had been partly dismembered and probably skinned prior to disposal.

All the horses were mature males (with well-developed canine teeth), 12-13 hands high, and some showing evidence of pathologies probably associated with traction and harnessing.

One skull showed evidence of pole-axing and knife cuts were present on the frontals. The height of the upper second premolar suggested an elderly individual of at least 19 years (after Levine 1982).

The teeth from this individual were of particular interest since there was wear on the upper canines and incisors (shown in a detail from a photograph by Kate Warren of Verulamium Museum in Fig. 14, opposite), revealed the canines worn flat with a stepped ridge around the edge. The third incisors were worn with a notch towards the aboral edge more typical of a younger animal. The profile from the third to first incisor (aboral to oral edge) forms an arc.

The cause of this wear is unclear; the mandibles articulating with this skull are absent, so the state of the occluding teeth is unknown. Examination of skeletal material and living elderly geldings has not shown any similar pattern, although in the case of the geldings any irregularities would usually have been filed down. The condition most likely to give rise to this wear pattern is 'parrot mouth' illustrated by Huidekoper (1903, 138). He describes the upper jaw projecting in front of the lower, the resulting malocclusion giving rise to an arched wear pattern in the upper jaw with a deep notch on the third incisor. This is usually only seen in old horses and can affect the intake of

food if it restricts the opening of the mouth (*ibid.* 137). However, since Huidekoper states that with parrot mouth 'these deformities are frequently much greater on one side of the jaw than the other', it seems more likely in this case, where the pattern of wear is so similar on both sides of the jaw, that it is more likely to be the result of some behavioural problem.

The upper and lower canines do not normally occlude but in this specimen the upper canines have been worn unusually flat. These teeth are too far forward in the mouth to have been worn by chewing an ill-fitting bit (this usually affects the premolars, as seen in another skull and articulating mandibles from these pit fills). It is suggested that the shape of this particular wear may result from constantly clamping the teeth around something like a horizontal partition pole, wearing the teeth into an arc-shaped profile over a longer period of time. This is a habit likely to have arisen from boredom in stabling and is included by Huidekoper (*ibid.* 147) amongst a variety of irregularities of the enamel collectively attributed to 'crib biting', i.e. when 'an object is seized in the mouth'. Damage resulting from crib biting (often associated with wind sucking) is usually seen on the outside edge of the enamel, where the animal has repeatedly ground its teeth against something in the stable and is also evident to some small extent in this specimen.

A full report and further discussion of the entire assemblage from these pits will be published in due course. I would like to thank Prof. D. Brothwell (University of York), Dr J. Clutton-Brock (Natural History Museum, London), and Miss K. Whitwell (Animal Health Trust, Newmarket) for their advice, and Dr M. Armour-Chelu for drawing my attention to the Huidekoper publication.

## References

- Huidekoper, R. S. (1903). *Age of the domestic animals*. Chicago: Alexander Eger.
- Levine, M. (1982). *The use of crown height measurements and eruption wear sequences to age horse teeth*, pp. 223-50 in B. Wilson, C. Grigson and S. Payne (eds.), *Ageing and sexing of animal bones from archaeological sites*. *British Archaeological Reports, British Series* 108. Oxford.



Figure 14. Horse maxilla from Verulamium, showing wear on upper canines and incisors.

## BOOK REVIEWS AND NOTICES

Baker, Sue (1993). *Survival of the fittest*. Dulverton: Exmoor Books. ISBN 086183-220-5 Available from Rare Breeds Preservation Trust (RBPT), National Agricultural Centre, Stoneleigh, Warwickshire. £16.50.

This is a highly readable book comprising the history, evolutionary biology and behaviour of the Exmoor pony. The first two chapters describe the author's fascination with the Exmoor pony and its habitat and an evolutionary history of the horse in general, and this race in particular. She gives a particularly good account of the complex Holocene development.

Dr Baker (this volume includes the data gathered for her thesis) believes that the Exmoor pony has been *in situ* since glacial times. She next relates the Exmoor to other pony breeds and then relates their written history from medieval to modern times,

including the relevant history of the moor, including the formation and history of the breed society and notable owners and supporters.

Numbers were at their lowest in the 1940s when the meat-starved British public was prepared to eat them, but at least the society kept track of numbers; when they next reached danger point the Rare Breed Preservation Trust took them under its protective wing. Despite this, and the establishment of a herd in Scotland and another on a Danish island, the animals are still too few for comfort. They could still disappear as a gourmet dish on the Continent and their function as children's ponies. Some of them are successful as driving ponies, though of course pit ponies are no more.

The next few chapters deal with biological aspects of the ponies, and with moorland climate and survival rates, as well as a

detailed study of their diet, derived from an arduous study of faeces. Veterinary problems, in particular parasites, are included here.

The ponies live in a number of herds located in the different areas of Exmoor. Herd structure, recruitment and territorial relationships are considered, including stallion hierarchies. Dr Baker loves the moor almost as much as the ponies, and the reader will also learn a lot about moorland geography and ecology. The individual animals and their blood-lines are safely on the computers of the RBPT and it seems likely that they will continue to be 'survivors'.

The book is extensively illustrated with photographs, maps, tables and specially-commissioned drawings. Scholarly, well-researched and well-written, Dr Baker communicates her enthusiasm and leaves you with the desire to own one of these delightful animals, which I suppose was one reason for writing the book. There is an excellent index.

**Barbara Noddle**, Heath Bungalow, Nelson Road, Ystrad Mynach, Mid Glamorgan CF8 7BR, U.K.

---

### Markov Chains for the archaeologist: a short review of textbooks on ecology

This is a review with a standpoint which some colleagues would, I am sure, dispute, namely that archaeology is human ecology, and that environmental archaeology in particular needs to be informed by an ecological outlook. This point of view has been expressed at length by Butzer (1982), and more succinctly by Martin Jones and Ken Thomas in their responses to Bill Boyd's paper in an earlier *Circaea* (Boyd 1990). Fear not! The debate will not be reopened here. The purpose of this review is simply to take a look at some of the more generally available textbooks on ecology which grace our library shelves, and to which environmental archaeologists may turn for information and ideas. The review has its origins in part in persistent requests from students for sources in which to read up particular ecological topics, and in part in the realisation that ecology has moved on quite dramatically over the last decade, and that

environmental archaeology may not have kept up. The choice of books is a personal selection, not a comprehensive survey.

There is still much of value in some of the oldest texts in ecology, such as the writings of the late Charles Elton (1927; 1966) and of Sir Arthur Tansley (1946). As with many other disciplines, including archaeology, ecology seems to have had an early phase of broad-mindedness before received wisdom became too entrenched. Elton, in particular, approached the natural world with an eye for structure and interaction which later ecologists often seem to have lacked, and which is so valuable when trying to understand the fragmented palimpsest of the archaeological record.

Despite the value of these earlier texts, the earliest book likely to be widely read today is Odum's *Ecology* (Odum 1963; 2nd edition 1975). Odum's book was influential in its day, and still makes an interesting source to compare with more recent texts. It presents an integrative view of natural systems, working from the ecosystem level downwards. Thus the limitation of numbers, and the interplay of population growth rates and predation, are discussed after a general review of ecosystems. The outlook is essentially trophodynamic, and the book's origins in the 1960s show through in its attempts to equate human socio-economic systems with natural ecosystems, and the lengthy closing chapter on pollution and resources.

More recently, Odum has produced a second edition of his *Ecology and our endangered life-support systems* (Odum 1993), which develops this theme to a greater extent. Many of the diagrams, and not a little of the text of the 1993 book, draw on *Ecology*, and the text seems dated as a result. The section on successional theory, for example, could have been written a generation ago, and ignores the recent debate as to whether the concept has any useful meaning at all.

An unlikely choice for archaeology students, yet a uniquely valuable book, is Paul Colinvaux's delightful *Why big fierce animals are rare* (Colinvaux 1978). In a comparatively short text (a weekend's reading) which assumes little initial knowledge of biology, the author demonstrates a series of fundamental principles of ecology by addressing seemingly naive questions such as that which entitles the book. The rarity of

big fierce animals is used as a starting point for an account of trophodynamics, with energy attenuation between trophic levels being used to explain why top predators are uncommon. Other chapters ask why the sky is blue, why animals are territorial, and between them deliver a good account of both the theoretical and empirical underpinnings of modern community ecology. Colinvaux writes elegantly and with a certain dry wit, and it is no surprise to learn that another of his books, *Ecology 2*, is used in some North American universities as an exemplar on English Literature courses.

*Ecology 2* (Colinvaux 1993) is something of a *tour de force*. Intended as a student textbook, it proceeds from chapters which consider the autecology of individual organisms, on to the population ecology of single species, and thence to complex multi-species communities. There are fewer concessions here to those who want the answers without the evidence. For example, the Lotka-Volterra models of population flux are developed from first principles, and there is a pretty ruthless comparison of the competing theories of Lack and of Andrewartha and Birch on the regulation of animal numbers. Readers to whom calculus is something which develops on teeth will find some chapters rather alarming. None the less, the clarity with which complex ideas are set out, and the copious pertinent examples which illustrate fundamental points, make this an excellent book. The author is a palaeobotanist by persuasion, and there is a useful, if necessarily brief, dip into 'the ecologist's time machine', better known to us as environmental archaeology. So it isn't just a one-way flow of ideas!

Paul Colinvaux's books seem not to be well known in Europe. In contrast, Michael Begon pops up all over bookshop shelves, most conspicuously as co-author of *Population Ecology* (Begon and Mortimer 1986) and of *Ecology: individuals, populations and communities* (Begon, Harper and Townsend 1990). *Population Ecology* is a useful review of such topics as the regulation of population numbers and predator-prey interactions. As such, it gives the detail which underlies concepts such as optimal foraging theory, and which therefore have direct relevance to archaeology. The mathematics can be a little alarming in places, and less numerate colleagues (including this reviewer) might do better to seek sanctuary in Krebs and Davies' (1978) *Introduction to behavioural ecology*.

Begon *et al.*'s *Ecology* covers much the same ground as Colinvaux's *Ecology 2*, though with a rather different style. The contrast is that between a perky, directly appealing English text rather in the Open University style, and a quieter, more wordy American text, with more than a hint of Ambrose Bierce and Thoreau. *Ecology* is comprehensive, very thoroughly illustrated, well referenced, and probably the most useful all-round text which is likely to be available through a bookshop or institutional library. To sum up the difference, this reviewer tends to look things up in Begon *et al.*, whilst reading Colinvaux at length, for pleasure.

A recently published book which merits attention is Rory Putman's *Community Ecology* (Putman 1994). This is definitely a textbook from the 'new wave' of ecology, stressing, as Dirk Gently would have it, the interconnectedness of all things, and therefore that the study of communities is the quintessence of ecology. In a remarkably short book, Putman brings together the current state of our understanding of ecosystem function, covering observational data from 'real' systems, but stressing the advances which have been made in the theoretical modelling of systems and communities. The subtext is a search for pattern in communities, whether in terms of dynamics, composition, or structure. Our fragmented archaeological data lack pattern, of course, and we are often in the position of trying to reconstruct past communities of which we only have partial (in either sense) evidence. We tend to assume some degree of structure, therefore, some reliable patterns of trophic relationships and interactions which can be used to fill in the gaps in our data. Putman's book is thus valuable as an overview of what assumptions, if any, we may be able to make. It is also a splendidly opinionated book. The author has a point of view, and makes that very clear. It is heartening to read an author who is prepared to admit *I confess that at a personal level I have never found this rather nebulous, 'armchair' type of reasoning particularly convincing*, before going on to admit that experimental results seem to validate the armchair reasoning in question (Putman 1994, 44). There is even a diagram (fig. 9.3) which readers are actively encouraged to photocopy and modify.

This review set out to be selective, and a number of other books have been wilfully

ignored. Perhaps the main points to make are that the ecological literature is out there, that ecology has moved on since the days of Odum, and that environmental archaeology cannot ignore the research which is undertaken on modern communities and ecosystems. We are investigating past ecosystems, past communities, and must get beyond the simple business of 'environmental reconstruction'. All too often, that term encompasses nothing more than a sort of diorama, a static reconstruction into which we place plants and animals and soils, and in which nothing happens. Yet we know that real ecosystems are dynamic, and that the interest in them, indeed the motivation of them, lies in the interactions between their constituent organisms, and between the organisms and the abiotic milieu. Modern ecology is getting firmly to grips with the dynamics of communities, and environmental archaeology needs to be in close contact with developments in this research, though not in order to transfer concepts and principles blindly from neo- to palaeoecology. As Gee and Giller (1991) have cogently argued, that would be to ignore fundamental differences around, amongst other things, the time-scales of our respective observations. Equally, we should avoid developing 'archaeological' models from first principles which largely re-invent concepts and structures already worked-out and utilised in ecology (see, for example, the interesting but irritating paper by McGlade (1995). None the less, by keeping in contact with developments in neoecology, environmental archaeology can develop its own theory and interpretative methods in parallel with neoecology. To do that, we need to keep in touch with the parallel discipline, and that has been the purpose of this short, selective review.

## References

- Begon, M. and Mortimer, M. (1986). *Population ecology. A unified study of animals and plants.* (2nd ed.). Oxford: Blackwell.
- Begon, M., Harper, J. L. and Townsend, C. R. (1990). *Ecology. Individuals, populations and communities.* Oxford: Blackwell.
- Boyd, W. E. (1990). Towards a conceptual framework for environmental archaeology: environmental archaeology as a key to past geographies. *Circaea* 7(2), 63-79.
- Butzer, K. W. (1982). *Archaeology as human ecology: Method and theory for a contextual approach.* Cambridge: University Press.
- Colinvaux, P. (1980). *Why big fierce animals are rare. How the natural world works.* London: George Allen & Unwin.
- Colinvaux, P. (1993). *Ecology 2.* New York: John Wiley.
- Gee, J. H. R. and Giller, P. S. (1991). Contemporary community ecology and environmental archaeology, pp. 1-12 in D. R. Harris and K. D. Thomas (eds.) *Modelling ecological change.* London: University College London.
- Krebs, J. R. and Davies, N. B. (1978). *An introduction to behavioural ecology.* Oxford: Blackwell.
- McGlade, J. (1995). Archaeology and the ecodynamics of human-modified landscapes. *Antiquity* 69, no 262, 113-32.
- Odum, E. P. (1963). *Ecology: the link between the natural and social sciences.* New York: Holt, Reinhart & Winston
- Odum, E. P. (1993). *Ecology and our endangered life support systems.* (2nd ed.) Sunderland, Mass.: Sinauer Associates Inc.
- Putman, R. J. (1994). *Community ecology.* London: Chapman & Hall.
- Tansley, A. G. (1946). *Introduction to plant ecology.* London: George Allen & Unwin
- T. P. O'Connor**, Department of Archaeological Sciences, University of Bradford, Bradford BD7 1DP, U.K.
- 
- Christopher D. Morris and D. James Rackham (eds.) (1992). *Norse and later settlement and subsistence in the North Atlantic.* Department of Archaeology, University of Glasgow Occasional Paper Series No. 1. Glasgow: University of Glasgow, Department of Archaeology. ISBN 1 873132 40 9. 230pp., figures. £19.95 (paperback).

This volume is a collection of nine articles which, as the title suggests, deal mainly with palaeoeconomic evidence from Viking, medieval and post-medieval sites in the

North Atlantic regions. The preface explains that the volume springs from a number of studies and papers inspired by and resulting from a conference held in 1988 entitled *The Norse in the North Atlantic*. These are not the conference proceedings (published elsewhere) but are papers which had not been included there (or in other recent publications on the same general theme) 'for a variety of reasons', and the volume is intended as a companion to these other publications.

With this background in mind, it is not surprising that the collection does not cohere well as a single volume; but the individual articles are of considerable interest. The preface states that the publication does not aim for comprehensive coverage and indeed the geographical coverage is weighted towards Iceland (four papers) with only a single brief paper on Scandinavia, one apiece on Orkney, Shetland, and mainland Scotland, and with a final paper discussing sites in Greenland. The Faroes and North America are not represented. The articles vary considerably in content from, on the one hand, a general, wide-ranging discussion of evidence collected over decades in Greenland (McGovern's paper), to a very detailed description of environmental column samples from a single site in Scotland (Morris *et al.* on Freswick), on the other. Most of the papers, however, do focus on palaeoeconomic and palaeoenvironmental evidence to a greater or lesser degree.

The first short article by Martens makes a number of fairly general statements about marginal lands in Norway, and the farming and other subsistence strategies which are used to exploit them. Using post-medieval and early modern evidence to define four different farm types, an attempt is made to extrapolate back to medieval times. Recent work including evidence from the mountain areas of southern Norway is referred to. The second article (by Bigelow) entitled 'Issues and prospects in Shetland Norse archaeology' deals with, amongst other questions, the difficulties in establishing a reliable chronology for Shetland. The contribution of place-name studies is reviewed and the potential of archaeological research to push forward the frontiers, especially in the early *landnam* phase, is stressed. Optimism is expressed about the potential of the radiocarbon accelerated mass spectrometer (AMS) to produce a dating structure independent of the Orcadian

evidence. The author also stresses the need for archaeology to resolve the thorny issue of the 'Pictish-Norse interface' and to establish the character of the initial contact and continuing coexistence of the two cultures. A plea is made for more excavation to provide additional economic evidence from different types of sites, for more artefactual evidence, more pollen records, and to measure coastal erosion.

The third paper (by Batey, with Morris) deals with the excavation and recognition of a Norse horizontal mill at Earl's Bu, Orphir, in Orkney. The paper briefly describes the structural evidence and summarises the rich ecofactual material which was recovered. Both this and the artefactual evidence is still under research and the author stresses that this is a provisional summary.

The fourth paper (by Morris and Rackham, with contributions by Batey, Huntley, Jones and O'Connor) is one in a series of papers on the site of Freswick in Caithness. The paper presents a lot of data from environmental columns taken from midden deposits on the cliff-side and includes specialist discussions on snails, carbonised plant remains, marine molluscs and crustaceans, mammals, birds and fish. The dating of the midden presents a problem as, to some extent, does its relationship to the trenches which produced the medieval structural evidence. This too is something of an interim statement as the evidence from the bulk samples from this midden has yet to be studied. Given these unresolved questions and incomplete studies it is questionable whether all the data (which occupies one quarter of the volume) needed to be presented here or would have been better combined with the bulk sample evidence when that was available.

The next four articles turn to Iceland. Two are studies based on midden deposits from Svalbarð in Northeastern Iceland (Amorosi on climatic impact and human response, and Zutter on plant and land-use patterns). Amorosi looks particularly at the post-medieval and early modern evidence for 'hard times' during the Little Ice Age, documented in a number of historical sources. The midden provides evidence for changes in emphasis on different species through the eight centuries of the sites' occupation and for the increasing reliance on wild species. He uses this and other strands of evidence to identify increasing economic 'stress' and

examines the subsistence strategies adopted to counter it. Zutter's paper deals with similar questions, using the archaeobotanical evidence from the Svalbarð midden to chart changes in land-use and plant exploitation. The difficulties in recognising changes attributable to climatic as opposed to other factors (cultural, data survival, etc.) which affect the environmental record are discussed. The next paper (Buckland *et al.*) is another interim article presenting environmental results from excavations at Reykholt, Western Iceland. This paper demonstrates the value of statistical analyses in showing concentrations of, in this case, insect remains. Using this data the authors were able to draw conclusions about the functions of certain rooms, personal health and hygiene and to identify species which must have been introduced, probably through imported packaging material. The final Iceland article (by Amorosi *et al.*) deals with environmental evidence from the high status site of Bessastaðir. The paper explores the value of the palaeoecological record, as opposed to and in addition to the artefactual record, to reveal status, and finds evidence for the importation of valued and rare foodstuffs as well as incidences of unusual species such as walrus and polar bear not represented on other sites.

The final paper (by McGovern) draws on work carried out on Greenland's Eastern and Western Settlements since the turn of the century, to produce models of subsistence and settlement hierarchy. He examines the evidence for a more independent, internally structured society than has traditionally been suggested for these distant colonies. By comparing sizes of hall, byres and available pasture, he suggests that sites with larger storage capacities, especially the complex at Garðar, might have provided a 'buffer' against economic crisis for the smaller farms in their zone, in return for political support. He concludes with a plea for more excavation and the collection of more data.

The preface states that this volume is likely to be of interest to 'environmental archaeologists and palaeoeconomists'—and I'm sure that it is. The editors also hope that it will appeal 'to those concerned with Viking, Norse and medieval archaeology in general' and, writing as one of these, it does. It is, nonetheless, an oddly assorted collection and individual articles will have greater lasting value than others. What all articles do point to, especially those dealing

with Iceland and Greenland, is the great archaeological potential of these areas. Many sites are still unusually pristine—there has been little disturbance (except for sea-ice and coastal erosion) and in some cases tephra horizons might ultimately provide a critical chronological structure. This makes these North Atlantic sites not only valuable sources of information on Norse and later settlements but important test beds for wider archaeological and palaeo-environmental studies.

**Ailsa Mainman**, York Archaeological Trust, Piccadilly House, 51 Piccadilly, York YO1 1PL, U.K.

---

Lyman, R. Lee (1994). *Vertebrate taphonomy. Cambridge Manuals in Archaeology.* Cambridge: University Press. ISBN 0 521 452155 (hardback), 0 521 458404 (paperback). xxvi+524pp., figures. £55 (hardback), £29.95 (paperback).

This, the latest edition of the *Cambridge Manuals* series, covers the wide discipline of vertebrate taphonomy. Like its predecessors on aspects of environmental archaeology, this volume falls short of being a manual *per se*, an important point which is also made by the author. The content is directed at the researcher as a source book and fulfils this role admirably. All aspects of vertebrate taphonomy are covered, both theoretically and using examples (some in more detail than others), reflecting the author's own research areas.

The book has thirteen chapters, the subject matter of which is well chosen. It is very easy to dip into certain aspects of the subject, without a need to use the index as each chapter heading is very concise.

The volume begins with an overview of taphonomy and its role within vertebrate zooarchaeology. This is followed by a potted history of the subject which is both interesting and absorbing. It includes some revealing quotes from eminent nineteenth century palaeontologists—I leave you to find them for yourselves! Chapter 3 contains the meat of recent debates in taphonomy and delves into the philosophy and evolution of the subject. Uniformitarian principles are introduced at this point using modern 'actualistic' studies as the hub for taphonomic interpretations.



Chapters 4-11 contain the major contributions to vertebrate analysis in archaeology and describe, sometimes in greater detail than is perhaps necessary, a range of principles. Firstly, the biology of bone and teeth is discussed, followed by their comparative strengths and weaknesses. Skeletal structure is described for the main groups of vertebrates and this is followed by a series of chapters explaining zoo-archaeological principles in the recording, interpretation and reporting of vertebrate assemblages.

Chapter 5 covers vertebrate mortality and the first steps in taphonomic history—the skeletonisation, disarticulation, and scattering of hard tissue. The next chapter looks at the accumulation and dispersal of skeletal material by means both of experiment and of studies of modern and archaeological material. Chapter 7 explores the differential survival of skeletal material when subjected to a range of taphonomic processes. Butchery and other anthropogenically derived bone modifications are examined in the next chapter, bone artefacts (such as tools) and their consequent debitage being discussed in some detail. Chapters 9-11 explain the chemical, geological, and biological processes which cause modification to the individual skeletal element and the assemblage as a whole.

The examples used within the core of the work are almost exclusively mammalian, so the author has added examples using fish, birds, and amphibians in the penultimate chapter.

The final chapter attempts to bring the many strands of taphonomic interpretation together into a statistical model where all of the variables are considered. The author admits that we have a long way to go before we can achieve the overall interpretation of a given assemblage or skeletal element and present it as a complete taphonomic history!

The figures and tables vary in their quality and some look as though they have been pasted in by hand; this takes some of the shine away from the book. A range of fonts and line widths are used which also dulls the production of the volume; however, even the obviously digitised graphs and diagrams are readable. The photographs, on the other hand, are of very high quality. The publishers are to be congratulated on publishing both hard- and paperback

editions simultaneously, thereby putting this information within the financial means of most interested parties.

Lyman has led from the front in the field of mammalian taphonomy over the past decade and this comes through very strongly in the text. Overall, the content of the book is diverse but well partitioned into chapters and sections, making the reader comfortable with the development of the discussion. This book represents a major contribution to the subject of taphonomy and will be indispensable to students new to the subject as well as being an excellent source book for the established researcher. I strongly recommend this volume as an up-to-date reference book on a very dynamic subject. Indeed, it is worth having for the bibliography, alone!

**Brian Irving**, 19 Hebden Avenue, Moreton West, Carlisle, Cumbria CA2 6TW, U.K.

## BOOK NOTICE

Karali, L. (1994). *A bilingual dictionary of Archaeological—Environmental terms*. Athens: Bibliosynergatiki. 109pp. (Λεξικό Αρχαιολογικών — Περιβαλλοντικών όρων, με εισαγωγή στην Ιστορία της Αρχαιολογίας.) Price: about 1500 drachma (approx. £4). No ISBN.

The fast and unbalanced development of archaeology, characterised by big changes in a short time-span, has caused serious terminological problems. Part of the general effort to settle the terminological 'chaos' is the publication of this dictionary.

This book consists of an introduction of about 30 pages, where the problem of terminology is analysed and the history of archaeology is presented very briefly, and the dictionary itself, which occupies a further 55 pages. It is an English—Greek dictionary, interpretative for most of the terms, too. In general, the terms are followed by an abbreviation of the science they come from. A Greek—English list of terms exists, as well. The book is completed by some simple drawings, by an explanation about its scope and use, and by a select bibliography at the end.

This project has been initiated by Ms L. Karali, Lecturer in Environmental

Archaeology at the University of Athens. The writer of this notice has contributed actively herself, in close co-operation with Ms Karali. It must be mentioned that undergraduate and postgraduate students, as well as archaeologists, helped with comments.

The scope, the nature, and the value of the dictionary are as follows:

To make the English terms understandable in Greek, and also to exercise the Greek researcher in 'English orthoepy' regarding archaeology; the converse is also true, so from this point of view it could be useful to English-speaking researchers as well.

To prevent as far as possible the confusion of terms, the meaning of which sounds especially complex.

So it is mainly a reference book, useful for quick, easy and scientifically correct consultation.

2. The present edition is, of course, only the first attempt. It must be admitted that there are some printing mistakes, but intense efforts have been made to eliminate scientific errors. The second edition will be ready soon. The number of terms will be increased (to about 1,000 in total). The bibliography will be more extensive and brought more up to date.

3. The book may be useful either to archaeologists and students, or to the general public, as a short guide for the understanding of archaeo-environmental publications, but *not* to scientists who handle subjects of extremely specialised and difficult terminology.

4. The brief speculation on the history of archaeology is placed as an introduction, in order to stress the fundamental changes which have led to the sudden archaeological development and to the confusion of terminology. This is the reason the *extended* reference to the different scientific theories, which constantly appear as explanatory approaches in archaeology, has been considered useless for this dictionary.

5. Sometimes the Greek translation of an English term is proposed with reserve, but in general the modern Greek language is preferred.

6. The attempt to concentrate mainly anthropological, zoological, botanical, geological and ecological terms (both in English and in Greek), connected with archaeology and used by it, is original.

Greek and foreign authorities have appreciated the hard work involved in this project, which may help many people to enter the world of environmental archaeology with more confidence.

**Anastasia Tsaliki**, *British School at Athens, 52 Odos Souedias, GR-106 76 Athens, Greece*

---

The Editors of *Circaea* would like to offer their sincere apologies to all the contributors to this issue, and to the membership of the Association for Environmental Archaeology, for the unintentionally long delay in publication.

## *Circaea*

---

### Notes for Contributors

Articles for *Circaea* should be typed double-spaced on A4 paper with generous margins. Line drawings should be in black ink on white paper or drawing film, to fit within a frame 153 x 250 mm maximum. Captions should be supplied on a separate sheet of paper, and labelling on figures should either be in 'Letraset' (or an equivalent) or should be in soft pencil. Half-tone photographs can be accommodated, but authors wishing to make extensive use of photographs, or colour, should note that they may be asked to contribute towards the high cost of production. The editors will modify short contributions to fit the layout and convention of *Circaea*. The same principle will be applied to idiosyncrasies of spelling and punctuation. Scientific articles will be submitted to referees; authors may, if they wish, suggest suitable referees for their articles.

**TWO COPIES** of scientific articles should be submitted. Authorities must be given to Latin names, either at their first mention or in a comprehensive list, and species lists should follow a named checklist. References should follow the so-called 'modified Harvard' convention, but with journal titles preferably given in full, not abbreviated. *World List* abbreviations will, however, be acceptable if the author indicates a definite preference. For guidance as to the preparation and presentation of material for publication, contributors are referred to the British Ecological Society's booklet *A Guide to Contributors to the Journals of the BES*, and The Royal Society's *General Notes on the Preparation of Scientific Papers* (3rd ed., 1974). Text proofs of papers will be provided and these should be returned to the Editors within three days of receipt.

**Ten free reprints will normally be supplied to the authors of scientific articles; further copies will be available, if requested at the time proofs are returned, at a charge of 5p per side, plus postage.**

Please note: there are no fixed deadlines for receipt of copy; material will normally be dealt with when received and will, if suitable, be published as soon as possible.

The Editors, *Circaea*, c/o Environmental Archaeology Unit, Walled Garden, University of York, Heslington, York YO1 5DD, U.K., Tel. +44 1904 433848 (Harry Kenward)/433851 (Allan Hall) or Fax 433850 or email: [biol8@york.ac.uk](mailto:biol8@york.ac.uk)

## Contents

### Papers

- Application of Cladocera analysis in archaeology* (Ilona Polcyn) ..... 41
- When is a time-trend not a time-trend? Scale and profile  
at Bronze Age Phylakopi (Melos)* (Nick Winder) ..... 49
- Medieval and early post-medieval horse bones from Market Harborough,  
Leicestershire, England, U.K* (Ian Baxter). ..... 65

### Short contributions

- Unusual tooth wear on a late medieval horse skull from St Albans, Hertfordshire, U.K.*  
(Alison Locker) ..... 80

- Book Reviews** ..... 81

- Book Notices** ..... 87

# *Circaea*