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Deterioration of archaeological bone – a statistical approach

Anders G. Nord*[1], Henk Kars[2], Inga Ullén[3], Kate Tronner[1] & Eva Kars[4]

** Corresponding author (anders.nord@raa.se)*

[1] National Heritage Board of Sweden, P.O. Box 5405, SE-114 84 Stockholm, Sweden
[2] Institute for Bio- and Geoarchaeology, Vrije Universiteit, De Boelelaan 1085, NL-1081 HV Amsterdam, The Netherlands
[3] Swedish Museum of National Antiquities, P.O. Box 5428, SE-114 84 Stockholm, Sweden
[4] ADC Archeoprojecten, Nijverheidsweg-Noord 114, NL-3512 PN Amersfoort, The Netherlands

The degradation of archaeological bone material in Sweden was studied (i) by examinating bone specimens, the surrounding soil and the local environment at excavations in progress, and (ii) by studying the reports of earlier excavations. Conventional and multivariate statistical methods applied to the data sets show that the degradation increases with time in the soil, and that the recent soil acidification is disastrous for the inorganic fraction of bone material. It is also observed that calcareous soil, the presence of organic matter in the soil, a deep grave, or a coffin of wood usually has a preserving effect. The empirical fact that bones of children deteriorate more than those of adults is confirmed, but no clear relation can be established between bone deterioration and soil type. The deterioration of the organic content and the histological microstructure is to a large degree dependent on microbial attack and unknown factors such as diseases, living conditions, or burial traditions.

Keywords: bone degradation, acidification, environment, statistics, archaeological heritage

Introduction

Apart from the risk of plundering, there are many factors which threaten the long-term *in situ* preservation of our archaeological heritage. The acidification of lakes and soil, for instance, which is clearly attributable to anthropogenic pollutants, will also affect buried remains, especially in regions with non-calcareous bedrock (see Hallbäcken 1992; Hettelingh et al. 1993). So are archaeological remains safe in the ground, or should they be excavated to avoid irretrievable loss of valuable material and information? This is a central question in modern archaeological heritage management (cf. Kars 1998).

The deterioration of buried metal artefacts has been discussed by various authors (e.g. Scharff 1993; Mattsson et al. 1996; Wagner et al. 1997; Nord et al. 2002; Ullén et al. 2004), and the deterioration of archaeological bone in soil has also been studied (e.g. Gordon & Buikstra 1981; Hedges et al. 1995; Kars et al. 2002). Fresh bone is a complicated composite with about 70% (by weight) of inorganic calcium phosphates (mainly calcium hydroxy apatite), 22% of proteins (mainly collagen) and water, and many factors may affect its deterioration: changing pH and redox potential on account of soil acidification and pollutants, hydrological conditions, micro-organisms, etc. These have been investigated in an international research project within the Fourth Framework Programme of the EU (Kars et al. 2002) in which all relevant variables were evaluated statistically and bone preservation status and alterations were defined on three basic criteria:

- *Macroscopic preservation* (important for exhibition purposes) was classified by visual inspection. Variable: *Bpres*, defined on a scale from 0 (nothing left) to 5 (well preserved bone).

- The organic content was represented by the *collagen content* (important for DNA analysis, ^{14}C-dating, etc.). Variable: *Bcoll* (percentage of collagen by weight).
- *Histological condition* was classified by microscopic examination of thin sections. Variable: *Bhist* (cf. Hedges et al. 1995; Millard 2001; Jans et al. 2002, 2004).

Bones (mostly human) from excavations in progress in England, Italy, the Netherlands, Sweden and Turkey were used in the project, and 134 data parameters were recorded for each sample, including details of the surrounding soil, archaeological context and environment. The histology of the bone samples showed a great potential for estimating the degree of deterioration (Jans et al. 2002, 2004), while the extent of microbial attack was reflected in the distribution of the pore diameters, measured by mercury porosimetry (Nielsen-Marsh 1997; Kars et al. 2002; Turner-Walker et al. 2002). The statistical evaluation showed a significant correlation between deterioration and variables related to the bone sample and soil chemistry, but less clear results were achieved for variables defining the differences in archaeological context and environment among the participating countries. Accordingly, a study of a more homogeneous group of bone samples, namely bones from recently excavated sites in Sweden, is now reported, together with the results of a survey of reports on Swedish excavations carried out some years ago. A third possible approach, viz. to examine bone material from older collections, was considered, but this has not yet been undertaken, although this possibility was exploited in a parallel study of archaeological bronze artefacts in museum collections (Ullén et al. 2004).

Bone from recent excavations

The Swedish material included in the EU project contained around 100 bone samples ranging in original location from Scania (Skåne) in the south to a Stone Age site at Vuollerim in Lapland, together with 21 completely disintegrated human skeletons only identifiable as dark patches in the ground, although they may nevertheless provide important information on the harmful influence of the environment. Further material from other sites has now been included for which porosity measurements were made at the Swedish Ceramic Institute with a Micromeritics AutoPore III-9430 mercury porosimeter. An example of a result for one bone sample is shown in Fig. 1.

Altogether 92 human bones (including the completely disintegrated skeletons) and 62 animal bones were used for the statistical evaluation, which was focused on regression and correlation coefficients obtained from multivariate analysis. The human and animal bones were treated separately because their histology and archaeological conditions are different. The classification was performed as in the EU project (see previous section). After a close examination of all variables, it was found that they could be reduced to 80 in number, because many of the former project parameters were not applicable to the archaeology and environment of Sweden. Two systems, SIMCA (Umetri AB, Umeå, Sweden) and SAS (SAS Institute Inc., Cary, N.C., USA), were used for the multivariate statistical analysis.

SIMCA performs *principal component analysis* (PCA) to find similarities and differences among variables, and *partial least-squares projections to latent structures* (PLS), which is a regression analysis. Before analysis, the coordinate system is linearly transformed so that the centre of the data cluster is moved to origo. The data for each variable are automatically scaled to unit variance. Parameters with extreme variations, such as ion concentrations in soil, were subjected to logarithmic transformation. As it had not been possible to carry out all the stipulated chemical analyses on the heavily degraded bone samples, some values are missing in the data file. A

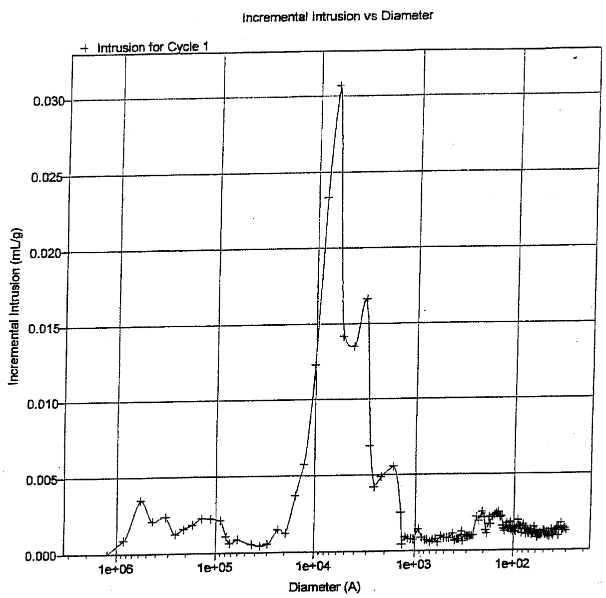

Figure 1. Mercury porosimetry data on incremental intrusion in bone sample Bi-8, a human mandibula from the Viking Age town of Birka. The large peak at 0.7 µm (7000 Å) corresponds to porosity caused by microbial attack. Note that the scale on the horizontal axis, in units of Å=10^{-10} m, is inverse and logarithmic (1e+04 Å means 10^4 Å=1 µm).

Table 1. Results of statistical multivariate analyses with SIMCA (regression coefficients, rc) and SAS (Pearson correlation coefficients, cc) with respect to macroscopic bone preservation (*Bpres*). hb=human bone, ab=animal bone.
*) Some data are missing for the animal bones (e.g. age at death, wooden coffin).

Variable	Explanation	SIMCA/hb	SIMCA/ab	SAS/hb	SAS/ab
	PRESERVING FACTORS				
Bcompl	completeness of skeleton (assessed by eye)	0.149	*	0.92	*
SpH	pH of surrounding soil (high pH preserving, low pH degrading)	0.108	0.117	0.90	0.61
Acofw	skeleton in a wooden coffin	0.074	*	0.45	*
Ecoast	found on the east coast of Sweden	0.072	0.033	0.80	0.73
Sloi	weight loss on ignition, reflecting the organic content of the soil	0.063	0.042	0.90	0.54
Bage	age at death	0.056	*	0.47	*
Bbulk	bulk density	0.048	0.031	0.32	0.40
Adepth	depth below ground	0.046	0.023	0.69	0.38
Scalc	calcareous soil	0.039	0.104	0.38	0.40
Bcoll	collagen content	0.014	0.072	0.14	0.64
	DEGRADING FACTORS				
Variable	Explanation	SIMCA/hb	SIMCA/ab	SAS/hb	SAS/ab
Ssilt	bone found in silt or clay	0.022	–0.080	–0.44	–0.07
Ssand	sandy soil	0.020	–0.022	0.31	0.04
Ewest	found on the west coast of Sweden	–0.029	–0.153	–0.33	–0.72
Bhist	histological quality, after Millard (2001), modified from Hedges et al. (1995)	–0.032	–0.009	–0.20	–0.27
Ay	time since burial in soil	–0.036	–0.032	–0.19	–0.20
Bint	total intrusion from Hg porosimetry	–0.038	–0.042	–0.30	–0.51
Sexch	exchangeable acidity of the soil	–0.039	–0.027	–0.64	–0.58
Bfiss	fissures (%) in a bone section	–0.042	–0.090	–0.81	–0.41
Efor	found in an acidic (pine) forest	–0.067	–0.088	–0.84	–0.63
Epoll	local polluting sources such as large industrial or power plants, heavy traffic etc.	–0.077	–0.026	–0.80	–0.55

missing value can be replaced by a value interpolated from the neighbouring data, but the SIMCA system excludes a variable with too many missing values, or one for which the data entries are too uniform to contribute significantly to the model. Accordingly, the 80 variables were further reduced to 57 for human bones and 48 for animal bones. The respective data files then contained 7% and 8% missing values.

PLS refinements were carried out with SIMCA for the three crucial preservation parameters *Bpres*, *Bcoll* and *Bhist* (see Introduction) as a function of all other variables.

A successful refinement necessitates that the number of observations (n), here bone samples, must be larger than the number of variables (K). This is fulfilled both for the human bones, with n=92 and K=57, and for the animal bones, with n=62, K=48. The PLS correlations are expressed in SIMCA by means of regression coefficients (rc) instead of correlation coefficients (cc) as in SAS. The rc:s give qualitative information about the effect of the various parameters on bone preservation (rc>0) or degradation (rc<0), but only in terms of semi-quantitative measures. Attention should be paid to the rc:s with the highest numerical values. Only variables having a value VIP>0.8 were considered significant (VIP=variable important for the projection). (For the present study this is almost equivalent to rc>0.03.) These variables are listed in Table 1. Note that a statistically significant value does not necessarily indicate a causal connection. There is a possibility of co-variance between two parameters, of which only one affects the bone. On the other hand, a statistically significant rc value is a pre-requisite for a cause-effect relation.

Many significant correlation factors were obtained for macroscopic preservation (*Bpres*), as discussed below, but the results for *Bcoll* and *Bhist* were less obvious, indicating that for these variables degradation partly depends on factors which are unknown and not reflected among those chosen. The histological structure and porosity data nevertheless indicated that microbial attack is common (e.g. Nielsen-Marsh 1997; Kars et al. 2002, 2003; Jans et al. 2002, 2004).

The animal bones were less uniform than the human material, partly because there are many animal species to consider and partly because the bones had usually been left in household deposits without any flesh remaining on them and had often been cooked or grilled. In spite of this, the results for the human and animal bones were usually similar (cf. Table 1 and below). In rare cases an animal had been buried with a human body, and with all conditions equal, the animal bones were found to be better preserved than the more porous human ones.

The Pearson correlation coefficients (cc) calculated using the SAS system (Table 1) should be distinguished from the regression coefficients (rc) obtained by SIMCA. We chose to avoid samples with incomplete data and variables that excluded too many observations, having checked that alternative predictor sets produce at least the paramount explained variance. A Pearson correlation coefficient should have a numeric value cc>0.3 to be considered as having any significance (Angsmark 1968; pers. comm. B. Areskoug, Chalmers University of Technology, Sweden). The minimised error variance is compared with the total variance, which corresponds to a model without predictor information. Their ratio is the degree of error reduction, and the complement to 1 is called the *proportion of explained variance* and denoted by r^2, for which a value above 0.50 is usually considered a useful model. The proportion of explained variance (r^2) was calculated for the three crucial preservation variables with respect to the eight most important factors as selected by the program system. For *Bpres* the r^2 value was as high as 0.93, which is better than for the complete EU project material with its 300 bone samples (r^2=0.80). The values for *Bcoll* and *Bhist*, though, were only around 0.45, which indicates that the degradation largely depends on unknown factors.

Our statistical evaluations, whether obtained by SIMCA or by SAS, show that the results regarding the macroscopic appearance (*Bpres*) are straightforward and similar for human and animal bones (Table 1). Acidic soil is clearly detrimental to the inorganic bone fraction, while a calcareous soil has a preserving effect. Although a large part of the degradation must have occurred during the last century, due to soil acidification, the archaeological age is nevertheless important. Accordingly, bone material from the Stone Age had generally deteriorated more than bones from later periods. Not surprisingly, there was a close correlation between the degree of preservation (*Bpres*) and the completeness of the skeleton (*Bcompl*) in the case of human remains. The empirical fact that bones from children (0–12 yrs) deteriorate more readily than bones from adults (20–40 yrs), all other factors being equal, was verified here. A deep grave (*Adepth*), a wooden coffin (*Acofw*), and organic matter in the soil (*Sloi*) seem to have had a preserving effect. A grave with a superstructure seems to have offered some protection (average rc around 0.03) by comparison with a flat, shallow grave (rc around zero). On the other hand, there was no clear indication of the influence of soil type. It may be that the differences between soil types reflect the consequences of the living conditions available for micro-organisms rather than the soil itself (cf. Nicholson 1996).

As regards the results for collagen content and histology, the bone chemistry and histology variables were usually correlated. Apart from this observation, comparatively few relations were obtained by comparison with the results for the macroscopic appearance (*Bpres*). Some results may nevertheless be cited. The preservation of collagen was found to be somewhat favoured by acidic conditions (as distinct from *Bpres*), while a coffin of wood (rc=0.074) and organic matter in the soil (rc=0.063) seem to have offered protection against degradation. The collagen content decreases with time, although not linearly. The occurrence of lamellae, fissures and tunnels is correlated to the histological status. This observation and the porosimetry data are indicative of microbial attack. The low r^2 values for *Bcoll* and *Bhist* nevertheless indicate that there are many other deteriorating factors that are still unknown to us, possibly related to burial conditions and the interval between death and burial. It is also possible that living conditions and diseases may have caused bone lesions, e.g. osteoporosis, and hence accelerated deterioration in the soil.

Survey of excavation reports

This part of the study was based on a close examination of fairly recent excavation reports for five geographical regions. These were denoted as the South (the province of Scania), the West (the provinces of Bohuslän and Halland, with heavy pollution), the East (the provinces of Uppland and Södermanland), Gotland (an island in the Baltic Sea) and the North (the provinces of Härjedalen and Norrbotten, with unpolluted air and soil); cf. Fig. 2. The West, East and North regions predominantly contain non-calcareous bedrock, while the island of Gotland is underlain by calcareous rocks. Both types of bedrock occur in the South region. In total 354 inhumation burials from 48 sites were included in the survey, together with the Viking Age town of Birka (545 inhumations), excavated around 1870 (Arbman 1940, 1943; Gräslund 1980). Birka was treated as a separate region because of the early date of excavation and the large number of graves within a restricted area and period. The archaeological periods recognised for Sweden are the Stone Age (c. 10,000–1800 BC), Bronze Age (c. 1800–500 BC), Early Iron Age (500 BC–400 AD), Late Iron Age (400–1050 AD), Viking Age (800–1050 AD) and Medieval Period (1050–1500 AD).

The state of macroscopic bone preservation (*Bpres*) was classified on a scale from 0 (nothing left) to 5 (well-preserved bone), as described in the previous section, based on the information given in the reports. The completeness of the human skeleton (*Bcompl*) was also classified on a scale from 0 to 5 (0=no remains, 5=complete skeleton). No data for *Bcoll* and *Bhist* were available, but chronological data were given. The external grave structure was classified as a mound, stone setting, cairn, or flat grave, and the internal structure as a coffin of wood, coffin of stone, or no coffin. The soil type (grain size) was classified as moraine, clay, silt, sand, or gravel, and the topography of the site as hilltop, hill slope, or flat ground.

When interpreting the results, the geographical and chronological distributions of the material must be considered. Multivariate statistics was useless, because few data were analogous and there were many missing values. Instead the statistical facilities offered by Microsoft Excel were used. Excluding Birka, which is discussed later, the numbers of graves in the regions vary from 12 in the West to 229 in the East, and the numbers in the time periods from 6 graves from the Bronze Age to 185 from the Late Iron Age (cf. Tables 2–4). The representation of the archaeological periods varies between the regions, however, so that all the Gotland graves considered here are Late Iron Age or Medieval, for example, while those in the West are

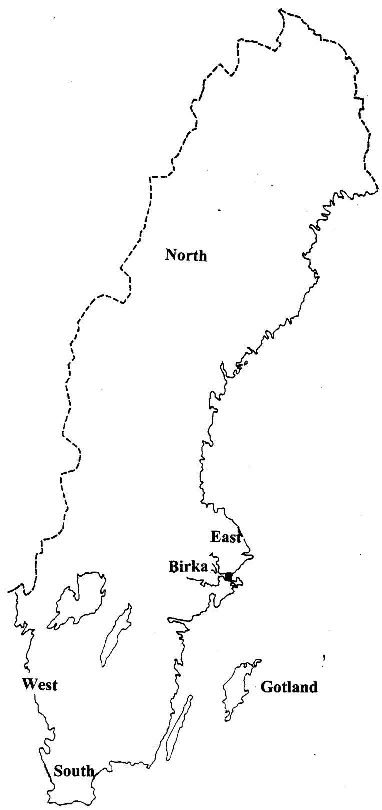

Figure 2. Map of Sweden showing the five geographical regions studied and the location of the Viking Age town of Birka (on a small island in Lake Mälaren).

Table 2. Geographical variation in the bone material. *AvBpres*=average of *Bpres*.

Region	Sites (n)	Graves (n)	*AvBpres*	Totally degraded bones (%)	*Bpres* range
South	4	28	1.4	43	0–5
West	7	12	0.5	63	0–3
East	28	229	1.1	51	0–4
Gotland	4	65	4.2	0	2–5
North	5	20	1.2	25	0–3
Birka	4	545	1.0	51	0–4
Total	48+4	354+545			

Table 3. Chronological variation in the whole material (excluding Birka). *AvBpres*=average of *Bpres*.

Archaeological period	Sites (n)	Graves (n)	*AvBpres*
Stone Age	10	27	1.3
Bronze Age	5	6	0.7
Early Iron Age	11	99	0.7
Late Iron Age	20	185	2.0
Medieval	2	37	3.3
Total	48	354	

from the Stone Age to Early Iron Age. The material cannot be regarded as representative of all the geographical regions or archaeological periods, but nevertheless some results were obtained. When comparing groups in terms of their macroscopic preservation status, the average *Bpres* value for a group is henceforward referred to as *AvBpres*. A striking difference in bone preservation (Table 2) was noted between Gotland (*AvBpres*=4.2) and the other regions (*AvBpres* 0.5–1.4). The bones from the polluted west coast with acidic soil were badly preserved, with *AvBpres*=0.5, and two thirds of the skeletons completely disintegrated. Furthermore, a pronounced difference in bone preservation was observed between areas with a calcareous bedrock (*AvBpres*=4.3) and those with a non-calcareous bedrock (1.1). The calcareous island of Gotland is the only region where no graves with completely disintegrated bone (*Bpres*=0) were reported.

There is some variation in bone preservation within the same site in all the regions (Appendix I). Note that in the East the larger Late Iron Age cemeteries often show wide variations, with *Bpres* varying from 0 to 4 within the same site. The whole material indicates an inverse correlation between time in the soil and preservation (Table 3, Fig. 3), but when each region is studied separately, it becomes clear that this is partly a bias due to the well-preserved material from Gotland. There is a tendency for better preservation in more recent bones, although there is no linear relationship between time in the soil and preservation. This is evident for the South, West and Gotland regions, but not for the East or North (cf. Table 4). However, since the Stone Age is only represented by a few graves in the East and North, this only shows that older bones *may* be better preserved than more recent ones and that other factors than the time spent in the soil have had a stronger impact on the preservation.

The large and fairly homogeneous material from the Iron Age in the East and from Birka was used to study the impact of external and internal grave structure and depth of the grave. For the Early Iron Age, the variation in *Bpres* for different external structures was negligible (*Bpres* around 0.5), but for the Late Iron Age material the East region and Birka display inconsistent results. At Birka, there was no great difference in preservation between bones from stone settings and those from flat graves, whereas in the East the bones from flat graves (*AvBpres*=1.8) were generally somewhat better preserved than those from stone settings (*AvBpres*=1.3).

The results are also inconsistent as regards the internal grave structure. For the Early Iron Age and Birka (Viking Age) material, there is almost no difference between graves with or without a wooden coffin (*AvBpres* around 1), in contrast to the result obtained from the above study of recently excavated bones. In the East region as a whole, bones in graves with a wooden coffin (*AvBpres*=1.7) appear to have been better preserved than those without a coffin (*AvBpres*=1.2), an effect that is likely to have been caused by variations in the local surroundings rather than by the structures *per se*. The depth of the grave, within the intervals normally found in prehistoric graves, was also examined (Fig. 4), and a slight tendency was observed for bones from deeper graves to be somewhat better preserved than those from more shallow ones. The soil type appeared to exercise no clear influence as regards degradation. In the East, with the greatest variety of soil types represented, the most favourable soil appeared to be clay (*AvBpres*=1.3), while the others had *AvBpres* around 1, but the difference is not convincing. Furthermore, the material could not be considered representative of the topographical variation in the regions, and hence meaningful comparisons were not possible.

Table 4. Chronological variation in the geographical regions. *AvBpres*=average of *Bpres*.

Region	Archaeological period	Sites (n)	Graves (n)	*AvBpres*	*Bpres* range
South	Stone Age	1	9	0.1	0–1
South	Early Iron Age	2	16	1.7	0–5
South	Late Iron Age	1	3	3.7	3–4
West	Stone Age	3	6	0.6	0–1
West	Bronze Age	3	4	0.5	0–1
West	Early Iron Age	1	2	1.5	0–3
East	Stone Age	2	8	3.0	3–4
East	Bronze Age	2	2	1.0	1–2
East	Early Iron Age	8	81	0.4	0–2
East	Late Iron Age	16	138	1.4	0–4
Gotland	Late Iron Age	3	44	3.8	2–5
Gotland	Medieval	1	21	5.0	5
North	Stone Age	4	4	1.5	0–3
North	Medieval	1	16	1.1	0–2
Birka	Viking Age	4	545	1.0	0–1
Total		48+4	354+545		

Discussion and conclusions

The results of the multivariate analyses of the recent excavation material, performed with the SIMCA and SAS systems, are in good agreement with each other, and the much less time-consuming examination of excavation reports also gave some results, which shows that this kind of documentation may be useful. The quality of a

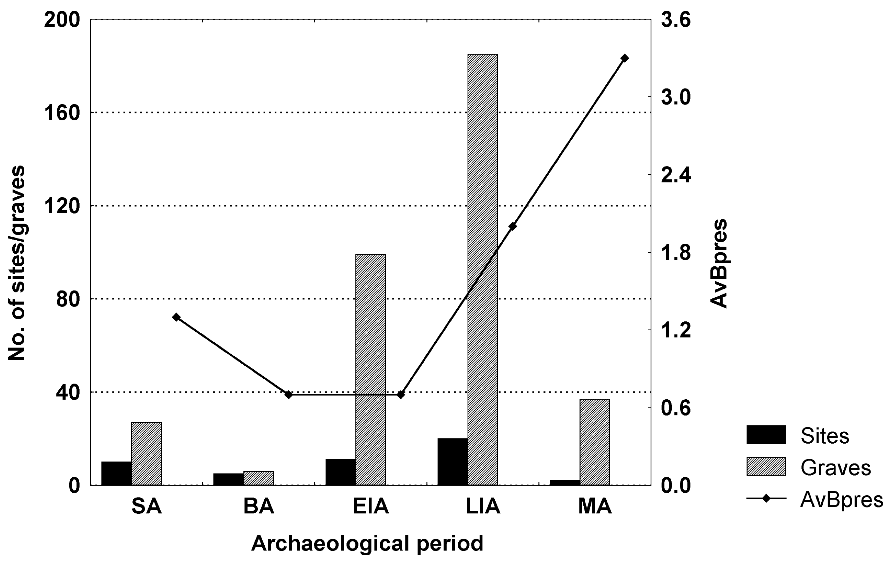

Figure 3. Sites and graves to which the archaeological bone material in the survey of excavation reports belonged. Abbreviations: SA=Stone Age, BA=Bronze Age, EIA=Early Iron Age, LIA=Late Iron Age, MA=Middle Ages. The average macroscopic bone preservation (AvBpres) for each period is indicated by the curve and the right-hand axis.

statistical analysis naturally depends on the amount of data and its availability, in which respect material from excavations in progress provides most data, while excavation reports may lack important information. This was particularly true for the oldest reports.

The statistical results allow some conclusions to be made on the degradation of bone material. Variables describing the environment were found to affect the macroscopic appearance (*Bpres*), collagen content (*Bcoll*) and histological microstructure (*Bhist*) of the samples in different ways. The chemical environment apparently primarily affects the macroscopic appearance, while micro-organisms, mainly bacteria and fungi, have an important influence on the organic content and histological microstructure (cf. Child 1995).

It is evident that soil acidification is detrimental to the macroscopic appearance of bone, as pointed out quite early by Gordon & Buikstra (1981). Such conditions are the most important factors causing degradation of bone apatite. On the other hand, acidic soils have not affected the histological microstructure or collagen content of the remaining bone. Calcareous soil is favourable for the preservation of the macroscopic appearance, as it counteracts the dissolving of bone apatite. Accordingly, the bones from Gotland were well preserved, while the conditions on the west coast, with acidifying pollutants, had caused severe degradation of the bone material. A soil with a high organic content seems to be protective, which may be related to its low oxygen content. In an interesting experiment, Nicholson (1998) buried bones in a compost heap that was rich in organic matter, and found most of them to be well preserved after seven years. However, she argues that this may be a consequence of the cross-linking of collagen with humics in the soil, resulting in a structure that is resistant to enzymatic attack. The influence of soil type, however, is not clear from our results, and more research is needed. The hydraulic conditions in the soil affect the supply of reactants to the bone surface and the removal of reaction products from it (Fetter 1994; Hedges & Millard 1995).

As regards the grave construction, a grave with some kind of superstructure usually seems to have offered protection against pollution. This was also reflected in the depth of the grave – the preservation being better in a deep grave than in a shallow one. The same observation has been made by Henderson (1987). A wooden coffin has obviously also provided protection for the skeleton, but not necessarily for the flesh (cf. Henderson 1987). This *might* be due to the anti-microbial activity of lignin phenols. Not surprisingly, there was a good correlation between the preservation status of individual bones and the completeness of the respective human skeleton. The archaeological age is important; the decay increases with the time since burial (note that extremely old bone material, e.g. dinosaur bones, will be petrified), but it is also clear that the degradation process may still continue, especially in regions with severe soil acidification. Moreover, bones from children were more degraded than bones from adults.

It is evident that micro-organisms cause degradation of organic bone material and the histological bone

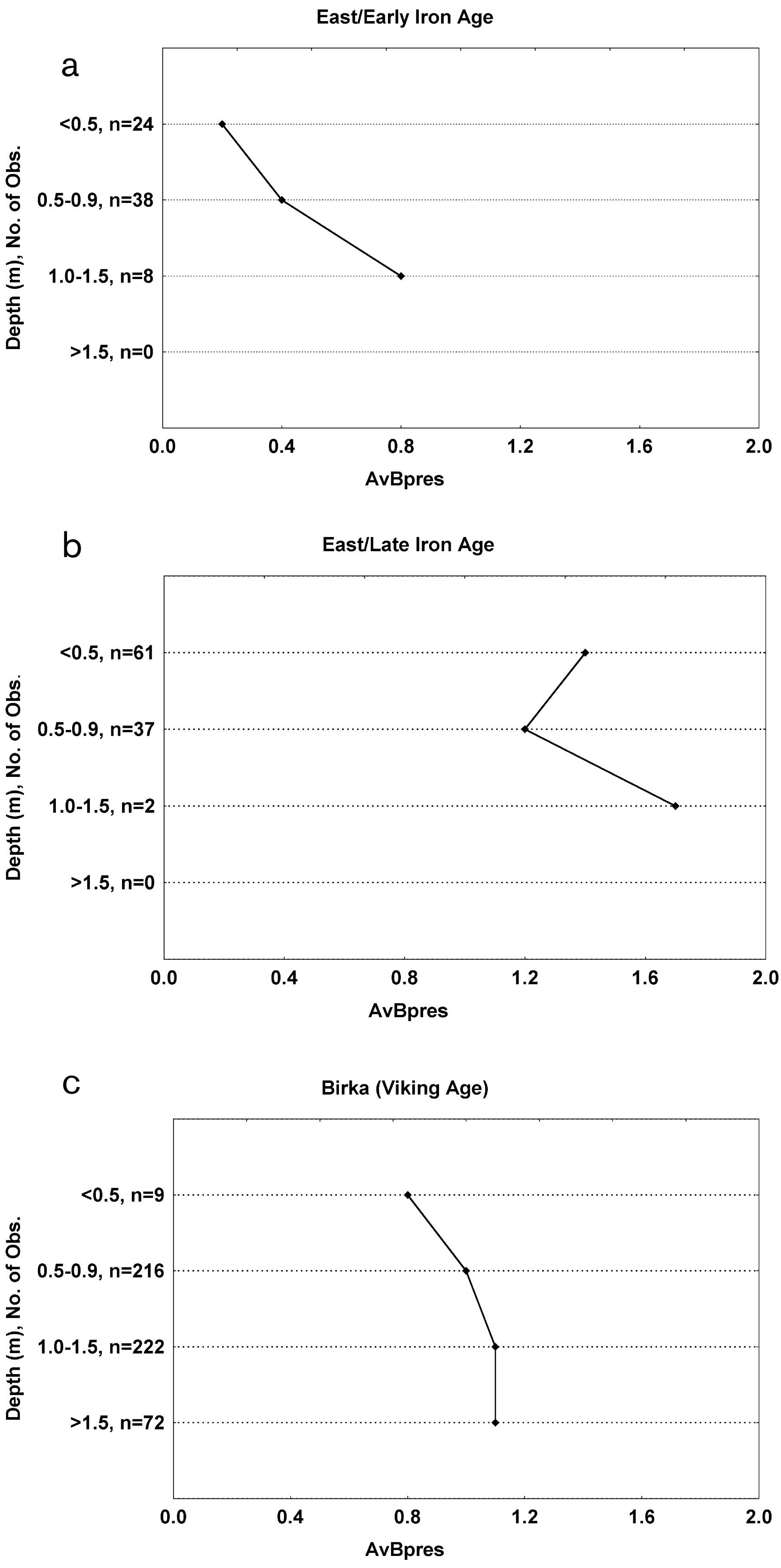

Figure 4. Average values for macroscopic bone preservation at various depth intervals in (a) Early Iron Age material from the east coast of Sweden, (b) Late Iron Age samples from the east coast, (c) the Viking Age Birka material (east coast).

structure (Kars et al. 2002). Unfortunately, the statistical analysis did not provide much insight into which other factors influence this degradation. Such unknown factors may be related to taphonomic processes which have affected the remains between the time of death and the burial (season of the year, climate, post-mortem interval before burial, burial traditions, use of a shroud etc.), and living conditions or diseases are likely to have some influence on bone degradation (Mant 1987; Hedges 2002). It is expected that detailed studies of well-documented material may answer some of these questions.

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Appendix I

Preservation and chronology for sites discussed in the excavation reports

Region	Site	Archaeological period	Graves (n)	*AvBpres*	*Bpres* range
East	Annelund	Stone Age	2	3.0	3
East	Korsnäs	Stone Age	6	3.0	2–4
East	Fjälla	Bronze Age	1	2.0	2
East	Albertsro	Early Iron Age	2	1.0	1
East	Carlslund	Early Iron Age	42	0.7	0–3
East	Dragonbacken	Early Iron Age	2	0.0	0
East	Fjälla	Early Iron Age	6	0.0	0
East	Graneberg	Early Iron Age	7	0.3	0–2
East	Rinkeby	Early Iron Age	1	0.0	0
East	Sigtuna 2:249	Early Iron Age	4	0.2	0–1
East	Tyttinge 1:1	Early Iron Age	17	0.1	0–1
East	Arninge	Late Iron Age	5	0.8	0–2
East	Gribbylund	Late Iron Age	4	0.5	0–2
East	Görla	Late Iron Age	12	2.8	0–4
East	Kalvskälla	Late Iron Age	9	1.2	0–3
East	Tibble	Late Iron Age	1	0.0	0
East	Täby raä75	Late Iron Age	4	2.2	2–4
East	Valsta	Late Iron Age	28	1.4	0–4
East	Väster Arninge	Late Iron Age	20	0.9	0–4
East	Almvägen	Late Iron Age	5	0.4	0–1
East	Edsviken	Late Iron Age	7	1.7	0–3
East	Gredelby	Late Iron Age	4	1.0	0–2
East	Lissma	Late Iron Age	3	0.0	0
East	Tors Backe	Late Iron Age	31	1.6	0–4
East	Viby gård	Late Iron Age	2	1.5	0–3
East	Stora Sundby	Late Iron Age?	1	0.0	0
East	Grönsta	(Late?) Iron Age	2	0.0	0
East	Lida säteri	Prehistoric (Bronze Age?)	1	0.0	0
Birka	Birka	Late Iron Age	545	1.0	0–4
South	Särslöv	Stone Age	9	0.1	0–1
South	Häljarp 1:6 o 2:5	(Early?) Iron Age	12	1.0	0–3
South	Hjärup	Early Iron Age	4	3.8	3–5
South	Trelleborg	Late Iron Age	3	3.7	3–5
West	Hunnebostrand	Stone Age	1	1.0	1
West	Sjöbol	Stone Age	1	0.0	0
West	Sannagård	Stone Age	4	0.7	0–3
West	Sannagård	Bronze Age	1	1.0	1
West	Mute	Bronze Age	1	0.0	0
West	Stum	Bronze Age	2	0.5	0–1
West	Spekeröd	Early Iron Age	2	1.5	0–3
North	Lillberget	Stone Age	1	1.0	2
North	Ansvar	Stone Age	1	3.0	3
North	Nedre Vojukkala	Stone Age	1	0.0	0
North	Finnäset/Menjärv	Stone Age	1	2.0	2
North	Vivallen	Medieval	16	1.1	0–2
Gotland	Fjäle i Ala	Late Iron Age	22	3.0	2–5
Gotland	Grodda 1:2	Late Iron Age	8	4.0	5
Gotland	Lilla Bjärge 1:17	Late Iron Age	14	5.0	5
Gotland	Banken 1	Medieval	21	5.0	5