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WHEN A ‘WATERHOLE’ IS FULL OF DUNG: AN ILLUSTRATION OF THE IMPORTANCE OF ENVIRONMENTAL EVIDENCE FOR REFINING ARCHAEOLOGICAL INTERPRETATION OF EXCAVATED FEATURES*

P. I. BUCKLAND†

Environmental Archaeology Laboratory, Department of Historical, Philosophical and Religious Studies, Umeå University, Sweden

and P. C. BUCKLAND

20 Den Bank Close, Crosspool, SheffieldS10 5PA, UK

Prehistoric field systems sometimes encompass excavated, pit-like features which are difficult to classify due to the complex stratigraphies resulting from reuse, infilling and collapse. They are frequently classified as wells and watering holes, but other potential uses for excavated depressions are rarely cited. We argue the need for environmental archaeology in the interpretation of features of this nature, and present a case study from a Bronze Age site at Podge Hole, near Peterborough (UK), where fossil insect material clearly contradicts the archaeological interpretation. We present empirical evidence for a sealed context filled with dung which cannot be interpreted as a water source. This evidence strongly contrasts with other superficially similar features at the site.

KEYWORDS: WATERHOLE, FOSSIL INSECTS, BRONZE AGE, ENVIRONMENTAL ARCHAEOLOGY, DUNG PIT, CONTEXT INTERPRETATION, COLEOPTERA

INTRODUCTION

The interpretation of pits cut to below the water table, associated with Bronze Age field systems as ‘waterholes’ for stock in an essentially pastoral economy, has become a *topos* of archaeological reports (e.g., Daniel 2009; Jackson 2015), but has often been advanced without regard to feature morphology, the taphonomy of any artefactual assemblage or environmental evidence. Any water source regularly visited by stock will rapidly show evidence of eutrophication, puddling of the access points and the development of a characteristic weed and insect fauna, essentially a watering hole (pond) rather than well. A pit used to draw water, better defined as a waterhole, will remain relatively clean; often, steep sides would be revetted with timber planking or wickerwork. Only after abandonment of its primary function would it be infilled, serving as a rubbish pit or allowed to silt up naturally, all of which will result in different plant and animal assemblages being included. Deeper structures, where drawing of water might require a mechanism or at least a rope with a bucket or robust pot, should be described as wells, although a gradation into waterholes will occur. Occasionally, deposits associated with the initial use

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†Corresponding author: email phil.buckland@umu.se

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phase of the feature may be defined, overlying primary sediments accumulated during the final phase of construction. Frequent cleaning out or re-digging may maintain the water source but any steep sides would be problematic for stock access. The difficulty for archaeologists when differentiating between very different types of structure and their different usage is often that field classifications are not revised in the light of environmental evidence before publication. This is typified by the analysis of the environmental evidence from the Bronze Age field system at Pote Hole, where the archaeological interpretation only partially included the ‘partially anomalous’ insect evidence, and suggested limited stock access to the ‘waterholes’ (Daniel 2009, 155). Rackham (2009, 162), in his review of all the environmental evidence, is more inclusive and suggests limited grazing of adjacent hedged meadows and perhaps hay fodder production. However, not all pits on the site that cut the water table were used as water sources and the insect evidence from one group, pit cluster 5, suggests a more specialist, if mundane, use. The interpretation of this feature forms the starting point for this discussion.

The site at Pote Hole

Archaeological excavation was carried out in advance of gravel extraction at Pote Hole, Thorney, 9 km north-east of Peterborough (Fig. 1; latitude 52.613°N, longitude 0.139°E). The site lies on the former fen edge at 5 m OD, between the small streams of Cat’s Water and the Thorney River, on a gently sloping Late Pleistocene gravel terrace of the River Nene (Briant *et al.* 2005), draining to the River Nene to the south-east. Until accelerated drainage in the 19th and 20th centuries, the landscape would have been a mix of rough pasture and wetlands, while presently the quarry sits in a sea of arable with any remaining peat rapidly desiccating. Mechanical removal of soil and immediate subsoil revealed a system of elongate rectangular fields and associated pits trending north-eastwards along the north-western fen edge (Daniel 2009, figs 2.1 and 3.1). The system, comprising 10 ditched fields in the excavated area, was laid out at right angles to

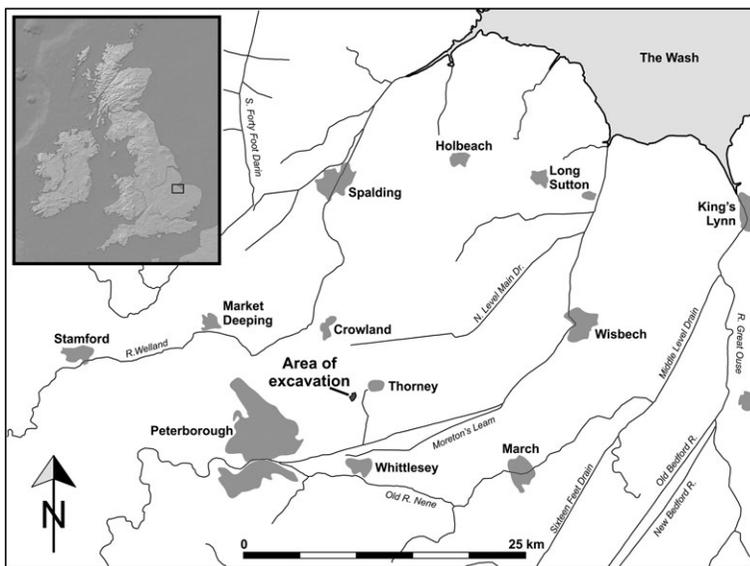


Figure 1 A map showing the location of the Pote Hole site.

a ditch running parallel to the fen edge. Several fields appear associated with ‘waterholes’, although direct stratigraphic relationships between field boundaries and pits were rarely clearly defined, partly because of the depth of ‘overburden’ removed in quarrying, but also, as the palaeoecological evidence suggests, because some boundaries may have relied more upon hedges than ditches (Fig. 2). Divisions between some fields were similarly not clear but the basic length of each of the major units, fields 1–4, was approximately 200 m; the width varied from 70 m to 180 m, although subdivision of the larger unit field 3 may not have been evident; and other fields to the north-east were smaller but on the same alignment. Funding was insufficient to allow study of the insect evidence from all waterlogged features and research was largely limited to ‘pond cluster 1’ in the eastern corner of field 5, from which three samples were

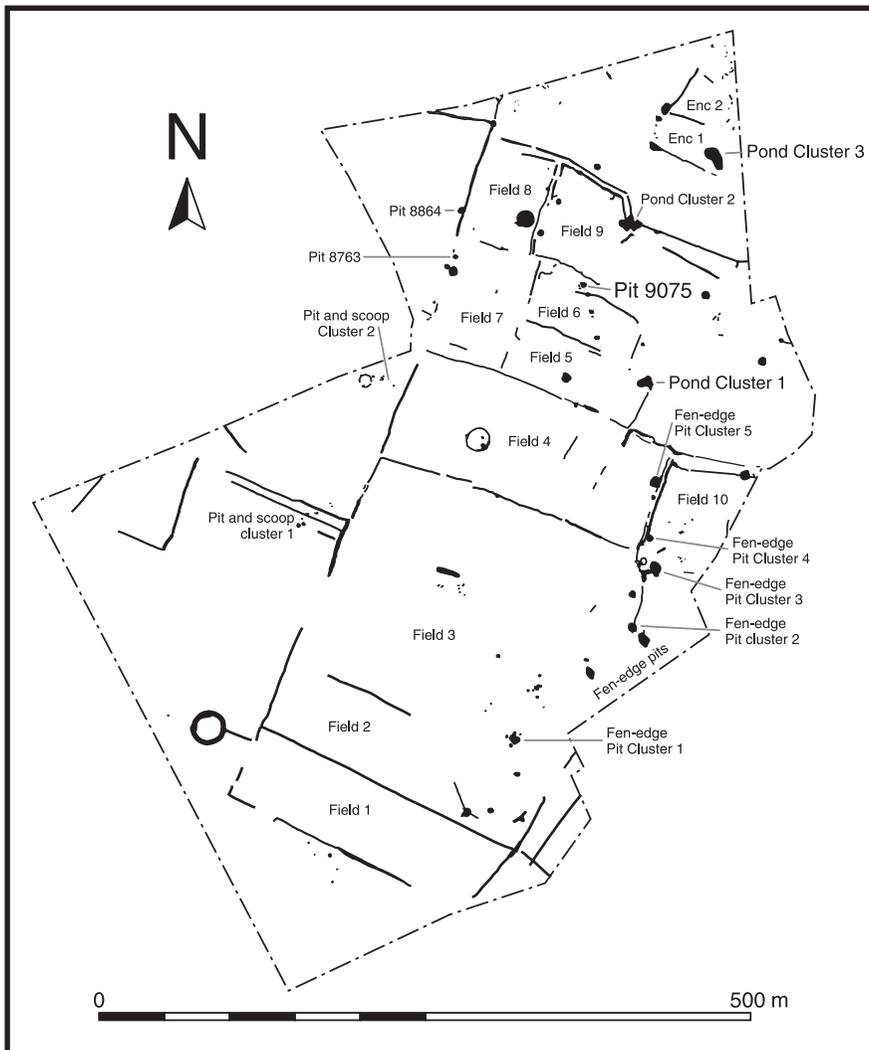


Figure 2 Site plans showing the locations of pits mentioned in the text in relation to the ancient field system. Modified from Daniel (2009) fig. 3.3.

examined, and single samples from ‘pond cluster 3’ in Enclosure 1, north-east of the regular field system, and ‘pit 9075’ (Buckland 2009). Plant macrofossils were identified from ‘Fen-edge Pit Cluster 5’ (Martin 2009, 97), but insect work on a sample from this feature was subsequent to the publication of the excavation report (Daniel 2009); its assemblage is sufficiently different from those recovered from other features to warrant further comment. The codes used for the identification of each cut, sample and context discussed are provided in Table 1, and the full species list for each context as online Supplementary Material.

MATERIALS AND METHODS

Pit cluster 5 (Daniel 2009, 38–9) consisted of several sub-circular to sub-rectangular recuts of a pit, approximately 4 m by 2 m, with the long axis parallel to and within the south-east boundary of Field 4, close to Field 10 (Fig. 3). It survived to a depth of 1.2 m below the stripped working surface of the quarry. The single sample was taken from the base of cut 8369, the deepest and stratigraphically probably the earliest pit. The latest phase of surviving recut of the pit has been dated to 1520–1400 cal. BC (Beta-238593), indicating a Middle Bronze Age origin. The infilling of this final pit included part of a wooden ladder and a possible ard (Taylor 2009, 117–19).

A sample (8394) of approximately 5 l was taken from context S8028, sealed in polythene and returned to the laboratory for processing. The material consisted of dark brown silty sediment with evident plant and insect remains. This was gently broken down over a 300 µm sieve and the material retained on the sieve placed in a bowl and paraffin (kerosene) added. This adsorbs on to the surface of the insect remains, which can then be floated off by the addition of water to the residue (Coope and Osborne 1968). The float was then sorted for insect sclerites under a low-power binocular microscope and taxa identified with reference to modern reference material and identification keys. The identified taxa, for all six samples, can be found in the online Supplementary Material and the open-access BugsCEP database (Buckland and Buckland 2006), in terms of minimum numbers of individuals (MNI). The taxonomy follows Böhme (2005).

Data analysis was undertaken by a combination of evaluation of the faunal implications of individual species and a broader, trait-based environmental reconstruction. The latter was undertaken for all six samples from the site in order to help understand the relative environmental implications of the sample faunas. Cluster analysis of the raw data was also performed to investigate the similarity of the sample species lists independently of the habitat implications of the faunas. Habitat data were extracted from the BugsCEP database and relevant literature. Environmental reconstruction was undertaken using the BugStats module and the traits database of BugsCEP (Buckland and Buckland 2006; Buckland 2014). The quantitative, trait-based approach to palaeoenvironmental reconstruction allows for the systematic analysis of fauna from different samples and sites. It also allows the results to be calculated in several different ways, given the same data set and database, and acts as a tool for interpretation, rather than a final

Table 1 *Identifiers used for the excavated features*

	<i>Pit</i>	<i>Pond 1</i>	<i>Pond 1</i>	<i>Pond 1</i>	<i>Pond 3</i>	<i>Pit 5</i>
Cut	9075	8291	8291	8130	9512	8369
Sample	8091	8016	8020	8009	8200	8394
Context	S9094	S8232	S8233	S8131	S9713	S8028

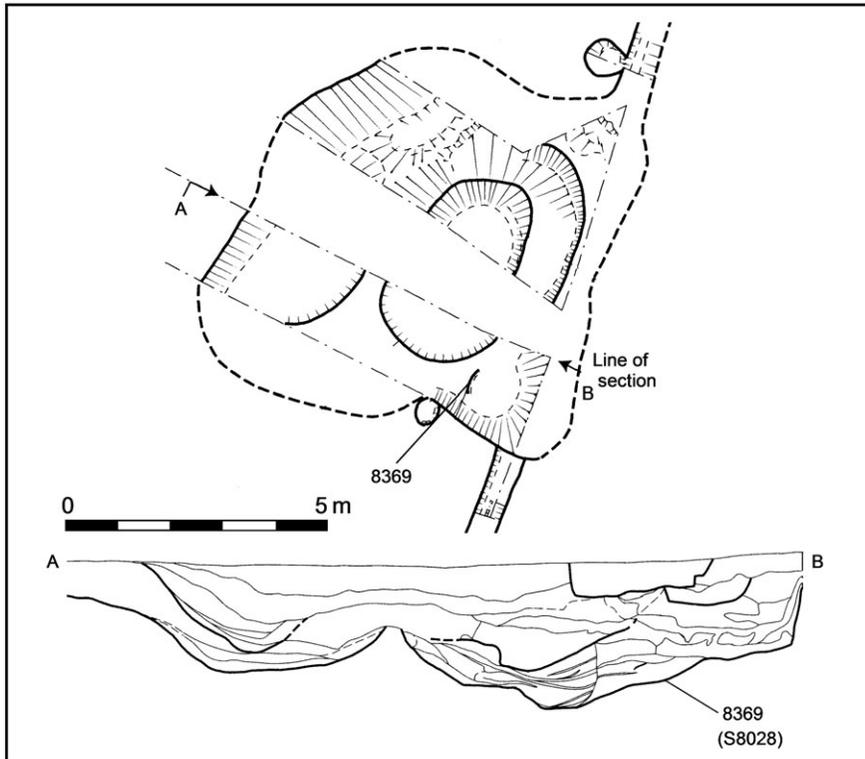


Figure 3 The stratigraphy of the pits described in the text. Modified from Daniel (2009) figs. 3.33 & 3.34.

visualization of results, where the implications of species abundances and taphonomic factors may be assessed.

RESULTS

The sample from pit 5 produced a significant beetle fauna including 153 specimens from 32 taxa, of which 42 fossils could be identified to species (Supplementary Material). Of the fossils, 86.31% were identified as belonging to potential dung taxa, and 84.31% as obligate dung Scarabaeidae. This is in stark contrast to the previously examined samples, where between 8.33% and 39.15% of the taxa were identified as potential dung species, and only 2.78–20.75% as obligate dung Scarabaeidae (Supplementary Material).

The dung fauna

While the five samples previously examined, from pond clusters 1 and 3 and pit 9075, provide a picture of an open pasture landscape, probably with some hedges and grazing animals (Buckland 2009), pit 5 indicates a much more immediate and specific use. The assemblage is dominated by one taxon, dung beetles of the genus *Geotrupes*, with over 100 individuals, of which 14 can be securely identified, on elytral fragments, legs and mandibles, as *G. spiniger* and one as its congener *G. mutator*. The large amount of fragmentary material makes estimation of numbers

of individuals difficult and the total count is based on the number of terminal abdominal segments, where identification has to be more tentative. While Smith *et al.* (2014) have suggested that it might be possible to suggest the donor animals from fossil dung beetle assemblages, it remains the case, as research by Landin (1961) implies, that the location and nature of the dung are of more significance. In addition, Smith *et al.*'s modern comparative samples contained remarkably few scarabaeoid dung beetles and *Geotrupes* and *Onthophagus* species were completely absent (Smith *et al.* 2014, table 1). Their results probably reflect the serious recent declines in dung faunas in general, occasioned by the use of ivermectin and other helminthicides (Sutton *et al.* 2014), since recent work with undosed Old English Longhorn cattle at Knepp in Sussex provided extensive faunas of *Aphodius* species and a few *Onthophagus* (Panagiotakopulu in prep.). *G. spiniger* remains the most frequently encountered member of the genus in lowland Britain. The female excavates a tunnel with side chambers beneath a dung pat, which it provisions with dung before laying an egg into each (Klemperer 1979); burrows may extend to 30 cm below the surface (Waßmer 1995). *Aphodius rufipes*, a single individual of which occurs in the sample, may be kleptoparasitic in the burrow (Klemperer 1980). The utilization of more amorphous dung accumulations rather than pellets restricts *G. spiniger* largely to the dung pats of larger animals and it has been widely recorded in horse and cattle dung (e.g., Donisthorpe 1939; Koch 1989). Both occur in the bone assemblages from Pode Hole, although the latter dominate (Rackham 2009). *G. mutator* has declined in frequency in the British Isles over the past two centuries and since 1990 has only been recorded from scattered single localities in Northumberland, Somerset, Dorset, Devon and Surrey (Lane and Mann 2016); there are also recent records from Knepp in Sussex, where helminthicides are not used on the free-ranging stock (Charles Burrell pers. comm.). Its sparse fossil record (Buckland and Buckland 2006) would also suggest that it has always been the less common species in England. Like *G. spiniger*, it breeds in burrows beneath dung pats; both species prefer dung on exposed, warm, sandy soils. Species of *Onthophagus* similarly prefer to burrow beneath dung on warm, dry soils, although the most frequent in the sample, *O. joannae*, is more catholic in its taste, occurring beneath sheep and rabbit dung (Koch 1989; Whitehead 2006), as well as occasionally that of other animals. The small histerid *Onthophilus striatus* prefers horse dung (Skidmore 1991), but is also recorded from rotting plant debris, other dung and fungi.

As noted by both Osborne (1982) and more recently by Robinson (2013a), the relative frequency of *O. fracticornis* and *O. similis* changes in the first millennium BC, with the former becoming rarer, declining almost to extinction by the last century, and the latter becoming the more frequent, if still less common than coprophagous species of *Aphodius*. Although these and other changes in the dung and pasture fauna partly relate to the loss of old pasture and the more recent wholesale use of helminthicides, they also have climatic implications; fossil beetle evidence suggests that, at least as late as the Middle Bronze Age, summers were probably significantly warmer, although the transition to a more wholly more oceanic regime appears to have been post-Roman (Kenward 2004; Buckland *et al.* 2016). Based on the dung beetle evidence from a much larger sample of sites than that available to Osborne (1982), Robinson (2013b) has put forward an argument for the period around c.1450 BC being about 2°C warmer than is current in south-central England. There is, however, a need to investigate these conclusions further in the light of evidence from interpretations based on other proxies, including bog surface water and pollen records (see Brown 2008).

Trait-based interpretation

While there are numerous ways to quantify insect biodiversity, archaeologists are usually most interested in the environmental implications of the collective habitats of the species found in any excavated context. Just as any radiocarbon date must be explained rather than discarded, the implications of the insect fauna retrieved from any sample can only be explained in terms of the depositional and surrounding environment (including any secondary deposition or mixing). If the fauna of multiple samples are treated to the same form of analysis, and the results uniformly scaled within each sample, quantitative comparisons may be made between samples (and even different sites; cf., Buckland *et al.* 2016). A trait-based environmental reconstruction, in which the specific or general habitat requirements of each species are compiled into an overview of the relative prominence of each habitat signal, can therefore prove both illustrative and useful for interpretation. This is especially true in the case of Pode Hole, where the sample in question dramatically stands out in the environmental reconstruction (Fig. 4). Despite large differences in numbers of taxa and individuals between samples, four of them (contexts S9094, S8232, S8233 and S8131) are remarkably similar in terms of their portrayal of an open pasture landscape. In Figure 4 (a), where habitats are scaled to take account of the number of individuals of each taxon, contexts S8028 and S9713 appear to stand out in terms of indications of dung-related and aquatic habitats respectively. This is a result of the superabundance of the aforementioned *Geotrupes* and species of the water beetle *Ochthebius* spp. the most probable species, *O. minimus* and *O. bicolon*, identified in samples, being associated with wet organic-rich mud rather than water. While this could be a good indication that the depositional environment lies close to that which is optimal for the species, the superabundance of individual species

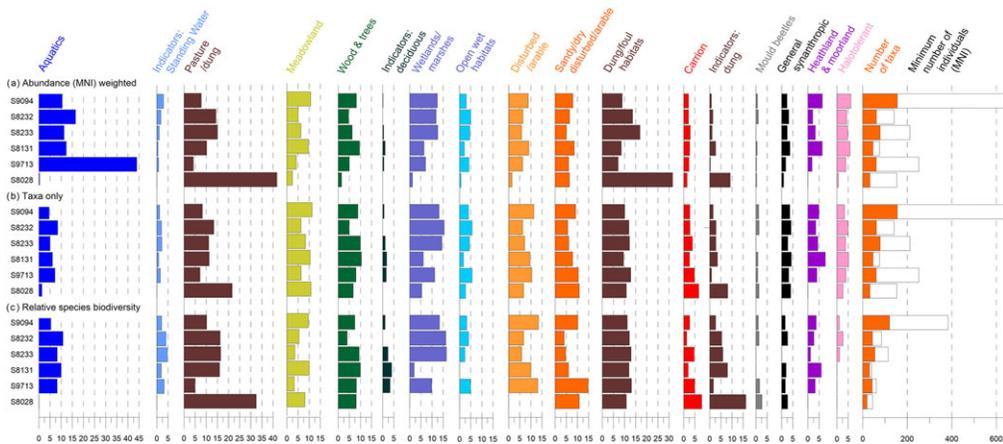


Figure 4 Trait-based environmental reconstruction for six samples from Pode Hole, with S8028 being the proposed dung pit. For each part ((a)–(c)), the same species list for each sample has been treated differently, but the sizes of the bars have been scaled to the total number of habitat indications within each sample, and are thus comparable between samples and figures (for the full methodology, see Buckland 2006). The x-axis indicates the relative importance of each habitat class in each sample, as indicated by three different aspects of the fauna: (a) assigns significance to the abundance (minimum number of individuals, MNI) of each species when defining the strength of each habitat signal; (b) removes the abundance, and uses the presence of each taxon only; and (c) reduces this further to only the presence of taxa identified to species level (essentially the species biodiversity). Note that any taxon may be present in more than one habitat class, and that the total sum of habitat representations, by which each sample is standardized, may be greater than the number of taxa or individuals providing the indications. [Colour figure can be viewed at wileyonlinelibrary.com]

may obfuscate details in any statistical analysis. Figure 4 (b) therefore removes the abundance weighting and provides a reconstruction based on the presence only of each taxon in the assemblage for each sample. The dominance of *Ochthebius* is thus removed from the habitat reconstruction, giving context S9713 a similar appearance to those above it in the diagram. The pasture/dung signal in context S8028, however, remains strong at over 20% of the habitat signals, indicating that this habitat is not only represented by large numbers of individuals, but also a larger number of taxa than others. Restricting the data to identifications with higher taxonomic resolution, essentially enforcing a taphonomic restraint, often has the effect of removing general background signals from a reconstruction. In this case, with a few exceptions, the signals for all samples but S8028 remain quite similar when only species-level identifications are used. The pasture/dung and indicator dung signals for S8028 are enhanced, indicating a robust reconstruction at the species level. (The Indicators:dung class is used only at the species level, and indicates obligate dung species.)

In a trait-based environmental reconstruction, context S8028 thus distinguishes itself from the other samples irrespective of statistical treatment. By statistically simulating different taphonomic resolutions, we can be confident that this is a robust reconstruction, which is not the result of differing taphonomic circumstances. While Figure 4 provides an overview of the habitats and a basis for differential interpretation of the samples, cluster analysis can provide an alternative statistical comparison of samples without attention to the ecology of the insects (Fig. 5). The results show a clear separation between S8028 and the other contexts, both when (a) the abundance of each taxon is taken into account and when presence only data are used (b). Case (a) is most easily explained by the low numbers of *Ochthebius* spp. and abundance of *Geotrupes* spp. relative to the other contexts, and (b) by the lower, and generally complementary, biodiversity of S8028.

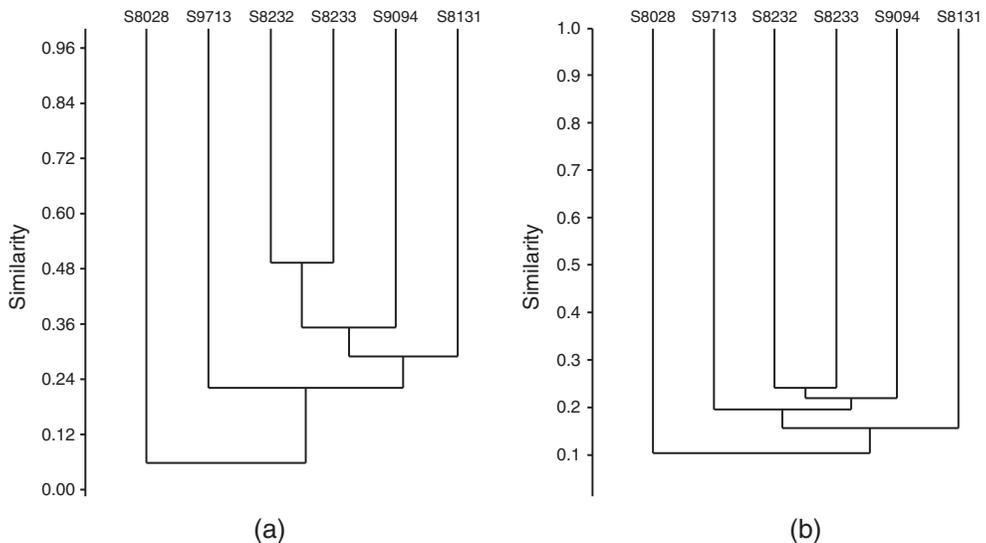


Figure 5 Cluster analysis on the Pote Hole beetle faunas using (a) the Bray–Curtis index of similarity, which takes differences in the abundance of individual taxon into account, and (b) Jaccard's similarity coefficient, which only uses the presence of taxa for comparison. (calculations undertaken with PAST3; for details of the calculation, see Hammer 2013).

Comparison with other sites and contexts

Compared with both fossil and modern collecting data, the assemblage from pit 5 at Podge Hole is unusual. Few sites produce such an overwhelming, in both absolute and relative terms, abundance of fossorial (burrowing) dung beetles to the exclusion of other elements in the dung fauna, and only the Roman well at Walton Cardiff in Gloucestershire approaches the numbers of *Geotrupes* at Podge Hole (Buckland and Buckland 2006; Tetlow 2008). Setting aside single occurrences of relatively common taxa as resulting from accidental inclusion either from flight or casual ingestion by stock, and background from adjacent pasture and possibly hayfield, the dung fauna remains unusual in the virtual absence of associated taxa. Species of hydrophilid and staphylinid beetle and Diptera are not present in the sample, where all would have been equally rapid colonizers of cattle dung pats (cf., Skidmore 1991; Smith *et al.* 2014). Selection from dung pats by either mammal or bird is one possibility. Large numbers of *Geotrupes* have been noted from badger latrines during late summer and autumn, when the adult beetle is most frequent (Jedrzejewska and Jedrzejewska 1998), but the omnivorous activities of the badger would have introduced other elements to the assemblage (Colin Howes pers. comm.). A corvid, exploiting a late-season abundance of dung beetles, could provide a sample biased towards the larger beetles in its cast pellets (Meyer *et al.* 1994; Horgan and Berrow 2004), but both modern and fossil evidence (cf., Girling 1977; Robinson 1991) show packing of sclerites within each other and this was not evident in the pit sample, although it did occur in a sample from pond cluster 1 (Buckland 2009). It is therefore probable that the fossorial dung fauna sought out material already buried in the pit in which to oviposit. Although many dung beetles are able to exploit similar accumulations of decaying plant debris and occasionally carrion, *Geotrupes spiniger* appears to be confined to dung, usually that of larger herbivores. The absence of the faunal elements associated with plant decay, latridiids and cryptophagids in particular (note the low importance of mould beetles in Figure 4), would also suggest fresh dung rather than manure. The absence of other elements in the manure fauna would preclude a source in clearing out stalls. Although it remains possible that a particularly foul plant residue—for example, that from the retting of flax in a pit (cf., Andresen and Karg 2011)—might have attracted dung beetles; again other elements of the foul residue fauna (*sensu* Kenward 1978) would be expected in the assemblage. Similarly, if a water-filled pit acted as a pitfall trap, a more diverse fauna would have been expected, even if the pit was only able to capture a short span of time when *Geotrupes* were the dominant species in the landscape.

The inference, therefore, has to be that fresh dung, almost certainly that of cattle, was being collected and stored in a pit. The limited character of the fauna suggests that the pit was capped, perhaps with a layer of earth, and only fossorial species were able to locate and tunnel down into it. Alternatively, fresh dung could have been collected (and buried) in the summer, from cattle released on to land that had remained ungrazed during the winter and spring. Large numbers of *Geotrupes* tend to swarm rapidly to this kind of freshly deposited dung. This explanation would also not require the beetles to burrow through soil to reach the dung, although collection would have to have been immediate, before other elements in the coprophagous fauna could colonize. Collection data (e.g., Roslin *et al.* 2014, 99), however, indicate that the species is overwhelmingly active in late summer and autumn. Unfortunately, the depth of removal of overburden before quarrying had removed any evidence that might have existed for capping of the pit. The archaeological evidence for the frequent recutting of the pit (Fig. 3), however, might suggest that the temporary burial of significant amounts of freshly collected dung was a frequent, perhaps annual, late-summer or autumn activity.

Dung pits

Dung pits are something of an empirical mystery in archaeological terms. While they may be referred to in consultancy reports—as are waterholes, watering holes and wells—a formal, empirically defined description of the former is very difficult to find when it comes to Bronze and Iron Age sites. The terms defined during excavation tend to persist through into publications with little evaluation, unless evidence from laboratory analyses is obtained to help interpret the context. Medieval dung pits, at least some of which appear to be growing ('hot') beds, have been excavated in the Netherlands (Aerts 2016), but their urban context and relatively recent date may have limited relevance for interpreting prehistoric rural contexts. Retting of flax and hemp in pits that cut the water table is attested both ethnographically (Evans 1957, fig. 54) and archaeologically (Loughlin and Miller 1979, pl. 10; Andresen and Karg 2011), although there appear to be no relevant entomological studies.

There is widespread evidence of the use of dung for manuring fields in the archaeological record (cf., Jones 2012) but this does not require fresh, clean dung and may be detected by inclusion of other midden and stall waste. While Guttman *et al.* (2005) had suggested that the use of animal manure was not introduced to Britain until the Iron Age, Radley and Cooper (1968), based on artefact scatters, had previously suggested its use in the Neolithic, and more recent geoarchaeological research led by the same researcher on soils in fields in Ireland indicates manuring during the early Neolithic (Guttman-Bond *et al.* 2016), an interpretation in line with that from elsewhere in western Europe (cf., Bakels 1997; Bogaard 2004). At Thayngen-Weier in Switzerland, the presence of puparia of the house-fly *Musca domestica* in samples has been utilized to infer the use of stall manure on fields during the early Neolithic (Nielsen 1989). While Macphail and Linderholm (2004) highlight the need for more evidence for manuring in England during the Neolithic, in an overview of the data Macphail *et al.* (1990) had earlier noted evidence for manuring in the early Bronze Age at a site on the Thames terraces beneath London, and geochemical studies suggest that manure was an important aspect of agricultural improvement from at least the Iron Age in Scandinavia (Linderholm and Engelmark 1996).

While there is a tendency in archaeological interpretation to equate evidence for manuring with arable cultivation (e.g., Rackham 2009, 163), it is still normal practice to apply manure to hayfields, although usually this now takes the form of slurry (van der Meer *et al.* 1987), and there is palaeoecological evidence for use of midden material in landscapes lacking arable; for example, in Norse Greenland (Buckland *et al.* 2009). The surficial deposits over the free-draining sands and gravels of the Nene terraces consist of 'gravelly silty clay' (Daniel 2009, 5), which impedes drainage. Frequent cropping of hay from the fields adjacent to the pit would lead to depletion of nutrients and declining yields without manuring. There is a problem, however, in applying fresh dung to grassland, in that it results in 'scorching', damage to the sward caused by localized over-concentration of nutrients. The Classical writers on agriculture were aware of these problems. Varro, writing in the first century BC, notes the requirement for separate dung pits for new and old faeces and the need to cover the dung pit to avoid drying out (I, 13.4, transl. in White 1970, 133). More recent ethnographic sources point out that dung was layered with earth and allowed to 'mature'. Alternating layers of fresh dung, household midden, peat and/or turf were laid in heaps (cf., Anon 1918; Fenton 1978, 280–4) and left over the winter. As only the base of one phase of the Pode Hole pit survived below the water table, it was not possible to ascertain whether layering had taken place, although the surviving dung must have been sealed to attract the limited beetle fauna.

Alternative interpretations

A more specialist application for the dung from the pit at Pode Hole is possible. Burning of dung as fuel is widely recognized both in the ethnographic and archaeological record (Fenton 1972; Miller 1984; Shahack-Gross 2011), but this requires drying in suitably sized blocks, rather than temporary burial, thereby attracting a different insect fauna. Reynolds (1974), in his experimental work with Iron Age grain storage pits, drew on ethnographic examples of pits being sealed with cow dung. Daub for walling also usually utilized herbivore dung, mixed with straw and clay (cf., Clifton-Taylor 1987). Dung storage might reflect seasonal usage, perhaps repair to daub walls after winter, but it seems unlikely that pit storage would have been deemed necessary. An annual process of dung collection, perhaps by children tending the stock and rapid burial, a repeated activity allowing partial decay in storage before use as manure on hayfields, is the preferred interpretation.

CONCLUSIONS

As these results suggest, interpretation of excavated features purely on the excavation data is unlikely to explain their usage history. While the find of wooden planking and buckets may be considered conclusive evidence of a well, it will not help explain later usage phases after collapse. Features without the luxury of such finds are naturally more open to a diversity of stratigraphic interpretations, and can only be more deeply understood with the help of environmental and ethnographic evidence.

This paper only presents the beetle evidence, and the use of multiple proxies, including plant macrofossils, geochemistry and soil micromorphology would provide an even more detailed picture of the nature of the deposits and their depositional environment. While the combination of methods may not provide simpler interpretations, it always helps to illustrate the complexity of reality. If archaeology is to advance beyond a reliance on persistent in-field feature classifications, it is essential that multi-proxy analyses, in combination with appropriate sampling, are integrated into the excavation plan from the very beginning. It is also essential that those involved in the post-excavation science are also involved on site during the excavation process to ensure that enough samples are taken from appropriate and stratigraphically closed contexts in discussion with the field archaeologists.

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REFERENCES

- Aerts, S. E. I., 2016, Storytelling sclerites: a coleopteran analysis of late medieval Dutch manure pits, M.Sc. thesis, Department of Archaeology, Leiden University.
- Andresen, S. T., and Karg, S., 2011, Retting pits for textile fibre plants at Danish prehistoric sites dated between 800 B.C. and A.D. 1050, *Vegetation History and Archaeobotany*, **20**, 517–26.
- Anon, 1918, *Farmyard manure*, Leaflet 93, 1–8, Board of Agriculture and Fisheries, London.
- Bakels, C. C., 1997, The beginnings of manuring in western Europe, *Antiquity*, **71**, 442–5.
- Bogaard, A., 2004, *Neolithic farming in Central Europe: an archaeobotanical study of crop husbandry practices*, Routledge, London.
- Böhme, J., 2005, *Die Käfer Mitteleuropas*, K. Katalog (Faunistische Übersicht), 2nd edn, Spektrum Academic, Munich.
- Briant, R. M., Bateman, M. D., Coope, G. R., and Gibbard, P. L., 2005, Climatic control on Quaternary fluvial sedimentology of a Fenland Basin river, England, *Sedimentology*, **52**, 1397–423.
- Brown, T., 2008, The Bronze Age climate and environment of Britain, *Bronze Age Review*, **1**, 7–22.
- Buckland, P. C., and Daniel, P., 2009, Insect remains, in *Archaeological excavations at Podge Hole Quarry: Bronze Age occupation on the Cambridgeshire Fen-edge* (eds. A. Richmond and G. Coates), 102–4, 189–195, British Archaeological Reports, British Series, 484, Archaeopress, Oxford.
- Buckland, P. C., Buckland, P. I., and Panagiotakopulu, E., 2016, Caught in a trap: landscape and climate implications of the insect fauna from a Roman well in Sherwood Forest, *Archaeological and Anthropological Sciences*, **10**(1), 125–40.
- Buckland, P. C., Edwards, K. J., Panagiotakopulu, E., and Schofield, E. J., 2009, Palaeoecological and historical evidence for manuring and irrigation at *Garðar* (Igaliku), Norse eastern settlement, Greenland, *The Holocene*, **19**, 105–16.
- Buckland, P. I., 2014, The Bugs coleopteran ecology package (BugsCEP) database: 1000 sites and half a million fossils later, *Quaternary International*, **341**, 272–82.
- Buckland, P. I., and Buckland, P. C., 2006, BugsCEP coleopteran ecology package, IGBP PAGES/World Data Center for Paleoclimatology Data Contribution Series# 2006–116, NOAA/NCDC Paleoclimatology Program, Boulder, CO, USA (downloaded from www.bugscep.com 10 October 2016—versions: BugsCEP v7.56; Bugsdata v7.11; BugsMCR v2.0; BugStats v1.2).
- Clifton-Taylor, A., 1987, *The pattern of English building*, Faber & Faber, London.
- Coope, G. R., and Osborne, P. J., 1968, Report on the coleopterous fauna of the Roman well at Barnsley Park, Gloucestershire, *Transactions of the Bristol and Gloucestershire Archaeological Society*, **86**, 84–7.
- Daniel, P., 2009, in *Archaeological excavations at Podge Hole quarry: Bronze Age occupation on the Cambridgeshire Fen-edge* (eds. A. Richmond and G. Coates), British Archaeological Reports, British Series, 484, Archaeopress, Oxford.
- Donisthorpe, H. S. J. K., 1939, *A preliminary list of the Coleoptera of Windsor Forest*, Lloyd & Co., London.
- Evans, E. E., 1957, *Irish folk ways*, Routledge & Kegan Paul, London.
- Fenton, A., 1972, A fuel of necessity: animal manure, in *Festschrift Matthias Zender. Studien zu Volkskultur, Sprache und Landesgeschichte* (eds. E. Ennen and G. Wiegelmann), 722–34, Ludwig Röhrscheid Verlag, Bonn.
- Fenton, A., 1978, *The Northern Isles: Orkney and Shetland*, Donald, Edinburgh.
- Girling, M. A., 1977, Bird pellets from a Somerset levels Neolithic trackway, *Natura*, **102**, 49–52.
- Guttmann, E. B., Simpson, I. A., and Davidson, D. A., 2005, Manuring practices in antiquity: a review of the evidence, in *Fertile ground: papers in honour of Susan Limbrey* (eds. D. N. Smith, M. B. Brickley, and W. Smith), 68–76, Oxbow Books, Oxford.
- Guttmann-Bond, E. B., Dungait, J. A. J., Brown, A., Bull, I. D., and Evershed, R. P., 2016, Early Neolithic agriculture in county Mayo, Republic of Ireland: geoarchaeology of the Céide fields, Belderrig, and Rathlackan, *Journal of the North Atlantic*, **30**, 1–32.
- Hammer, Ø., 2013, PAST paleontological statistics, version 3.0: reference manual, University of Oslo.
- Horgan, F. G., and Berrow, S. D., 2004, Hooded crow foraging from dung pats: implications for the structure of dung beetle assemblages, *Proceedings of the Royal Irish Academy*, **104B**(2), 119–24.
- Jackson, R., 2015, *Huntsman's Quarry, Kemerton: a Late Bronze Age settlement and landscape in Worcestershire*, Oxbow Books, Oxford.
- Jedrzejewska, B., and Jedrzejewska, W., 1998, *Predation in vertebrate communities: the Bialowieza primeval forest as a case study*, Springer-Verlag, Berlin.
- Jones, R. (ed.), 2012, *Manure matters: historical, archaeological and ethnographic perspectives*, Ashgate, Farnham.
- Kenward, H. K., 1978, in *The archaeology of York, vol. 19, Principles and methods. Fasc. 1, The analysis of archaeological insect assemblages: a new approach* (eds. P. V. Addyman and H. K. Kenward), Council for British Archaeology for York Archaeological Trust, London.

- Kenward, H. K., 2004, Do insect remains from historic-period archaeological occupation sites track climate change in northern England? *Environmental Archaeology*, **9**, 47–60.
- Klemperer, H. G., 1979, An analysis of the nesting behaviour of *Geotrupes spiniger* Marsham (Coleoptera, Scarabaeidae), *Ecological Entomology*, **4**, 133–50.
- Klemperer, H. G., 1980, Kleptoparasitic behaviour of *Aphodius rufipes* (L.) larvae in nests of *Geotrupes spiniger* marsh (Coleoptera, Scarabaeidae), *Ecological Entomology*, **5**, 143–51.
- Koch, K., 1989, *Die Käfer Mitteleuropas*, *Ökologie 2*, Goecke & Evers, Krefeld.
- Landin, B. O., 1961, Ecological studies on dung-beetles, *Opuscula Entomologica*, Suppl., 19.
- Lane, S. A., and Mann, D. J., 2016, *A review of the status of the beetles of Great Britain: the stag beetles, dor beetles, dung beetles, chafers and their allies—Lucanidae, Geotrupidae, Trogidae and Scarabaeidae*, Natural England, Peterborough.
- Linderholm, J., and Engelmark, R., 1996, Prehistoric land management and cultivation: a soil chemical study, in *6th Nordic conference on the application of scientific methods in archaeology*, 315–22, Esbjerg Museum, Esbjerg.
- Loughlin, N., and Miller, K. R., 1979, *A survey of archaeological sites in Humberside*, Humberside County Council, Hull.
- Macphail, R. I., and Linderholm, J., 2004, Neolithic land use in South-East England: a brief review of the soil evidence, in *Towards a new Stone Age: aspects of the Neolithic in South-East England* (eds. J. Cotton and D. Field), 27–39, Council for British Archaeology, York.
- Macphail, R. I., Courty, M. A., and Gebhardt, A., 1990, Soil micromorphological evidence of early agriculture in north-west Europe, *World Archaeology*, **22**, 53–69.
- Martin, G. S., and Daniel, P., 2009, Waterlogged plant remains, in *Archaeological excavations at Pote Hole Quarry: Bronze Age occupation on the Cambridgeshire Fen-edge* (eds. A. Richmond and G. Coates), 97–102, British Archaeological Reports, British Series, 484, Archaeopress, Oxford.
- Meyer, R. M., Buckland, P. C., and Monaghan, P., 1994, The diet of the chough, *Pyrrhocorax pyrrhocorax*, as indicated by digested prey remains, *Avocetta*, **18**, 95–106.
- Miller, N. F., 1984, The use of dung as fuel: an ethnographic example and an archaeological application, *Paléorient*, **10**, 71–9.
- Nielsen, B. O., 1989, House fly puparia (*Musca domestica* L.) from a Neolithic field in Thayngen-Weier, Switzerland, *Mitteilungen der Schweizerischen Entomologischen Gesellschaft*, **62**, 5–8.
- Osborne, P. J., 1982, Some British later prehistoric insect faunas and their climatic implications, in *Climatic change in later prehistory* (ed. A. Harding), 68–74, Edinburgh University Press, Edinburgh.
- Rackham, J., and Daniel, P., 2009, The Bronze Age environment and economy of Pote Hole, in *Archaeological excavations at Pote Hole Quarry: Bronze Age occupation on the Cambridgeshire Fen-edge* (eds. A. Richmond and G. Coates), 159–63, British Archaeological Reports, British Series, 484, Archaeopress, Oxford.
- Radley, J., and Cooper, L. B., 1968, A Neolithic site at Elton: an experiment in field recording, *Derbyshire Archaeological Journal*, **88**, 37–46.
- Reynolds, P. J., 1974, Experimental Iron Age storage pits: an interim report, *Proceedings of the Prehistoric Society*, **40**, 118–31.
- Robinson, M., 2013a, The relative abundance of *Onthophagus* species in British assemblages of dung beetles as evidence for Holocene climate change, *Environmental Archaeology*, **18**, 132–42.
- Robinson, M., 2013b, Holocene archaeological evidence of extinct and very rare British Scarabaeoidea, *Environmental Archaeology*, **18**, 143–53.
- Robinson, M. A., 1991, The Neolithic and Late Bronze Age insect assemblages, in *Excavation and salvage at Runnymede Bridge, 1978: the Late Bronze Age waterfront site* (ed. S. Needham), 277–325, British Museum, London.
- Roslin, T., Forshage, M., Ødegaard, F., Ekblad, C., and Liljeberg, G., 2014, *Nordens Dyngbaggas*, Entomologiska Föreningen i Stockholm, Stockholm.
- Shahack-Gross, R., 2011, Herbivorous livestock dung: formation, taphonomy, methods for identification, and archaeological significance, *Journal of Archaeological Science*, **38**, 205–18.
- Skidmore, P., 1991, *Insects of the British cow-dung community*, Field Study Council, Preston Mountford.
- Smith, D., Nayyar, K., Schreie, D., Thomas, R., and Whitehouse, N., 2014, Can dung beetles from the palaeoecological and archaeological record indicate herd concentration and the identity of herbivores? *Quaternary International*, **341**, 119–30.
- Sutton, G., Bennett, J., and Bateman, M., 2014, Effects of ivermectin residues on dung invertebrate communities in a UK farmland habitat, *Insect Conservation and Diversity*, **7**, 64–72.
- Taylor, M., and Daniel, P., 2009, The waterlogged wood, in *Archaeological excavations at Pote Hole Quarry: Bronze Age occupation on the Cambridgeshire Fen-edge* (eds. A. Richmond and G. Coates), 113–25, British Archaeological Reports, British Series, 484, Archaeopress, Oxford.

- Tetlow, E., 2008, The insect remains, in J. Hart and E. R. McSloy, Prehistoric and early historic activity, settlement and burial at Walton Cardiff, near Tewkesbury: Excavations at Rudge Way lane in 2004–2005, in *Iron Age and Romano-British agriculture in the north Gloucestershire Severn Vale* (ed. N. Holbrook), 62–7, Bristol and Gloucestershire Archaeological Report **6**, Cirencester.
- van der Meer, H. G., Unwin, R. J., van Dijk, T. A., and Ennik, G. C. (eds.), 1987, *Animal manure on grassland and fodder crops: fertilizer or waste? Proceedings of an international symposium of the European Grassland Federation*, Martinus Nijhoff, Dordrecht.
- Waßmer, T., 1995, Mistkäfer (Scarabaeoidea et Hydrophilidae) als Bioindikatoren für die naturschützerische Bewertung von Weidebiotopen, *Zeitschrift für Ökologie und Naturschutz*, **4**, 135–42.
- White, K. D., 1970, *Roman farming*, Thames & Hudson, London.
- Whitehead, P. F., 2006, The puparium of *Onthophagus joanna* Goljan 1953 (Col., Scarabaeidae), *Entomologist's Monthly Magazine*, **142**, 52.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Data S1 Supporting information