Pact 26 - 5 : P.C. Buckland

Granaries Stores and Insects
The Archaeology of Insect Synanthropy

INTRODUCTION

Insects are frequently the most common identifiable macrofossils in anaerobic sediments (Buckland and Coope, 1985) and any archaeologist who has excavated in waterlogged sediments is likely to have observed the shiny fragments of insect cuticle often irridescent, which form the basis of palaeoentomological research. Similarly charring of material, usually either dung or cereals, can lead to the preservation of included insect remains (Osborne, 1977 ; Buckland, 1982). Until only twenty years ago, however, rarely were such observations regarded as a potential source of archaeological information and the subject still lags far behind several other palaeoecological techniques, such as palynology and plant macrofossil studies, widely appealed to in a subject which has become increasingly orientated towards human impact on the environment rather than a study of artifacts. The latter approach remains typified by Howard Carter's reaction to the remains of insect pests of stored products from the tomb of Tut'ankhamun ; to him, these were insufficiently interesting to merit inclusion in the monograph and the disappointed entomologist Alfieri (1931), had to publish elsewhere. The problem of achieving balance between palaeoecology and archaeology continues and important lists of biota are still often relegated to archive (e.g. Smith, 1981) or, in Britain at least, to an impossible-to-read microfiche (e.g. Robinson *et al.*, 1984) ; such an approach is sometimes used as an excuse for the summary treatment of important data. Attitudes and availability of suitably trained researchers add further problems to any attempt to synthesize the results of past work which has inevitably a bias towards sites in England, where the Birmingham group of Quaternary entomologists have been active since the late 1950's (for review, see Buckland and Coope, 1985) ; only with the development there of an efficient recovery technique, however, that of paraffin (kerosene) flotation (Coope and Osborne, 1968 ; Coope, 1986) could efficient large scale recovery, from an average sample size of 3-5 kg, be practised. Previous work had involved either casual recovery during other studies, often of the remains of stored products (e.g. Zeitschek, 1956), or the tedious splitting of sediments along any bedding places, sometimes leading to the chance retrieval of evident insect, usually beetle, remains (e.g. Kimmins, 1954).

Such comments might seem of limited, specialist, interest but for two significant points : particular species may be restricted to very particular environments (stenotopic) and individual taxa appear to have been both morphologically and ecologically stable for much of the Quaternary at least (cf. Coope, 1979 ; Hennig, 1966). The archaeological record of those species closely associated with man, the synanthropes, includes a number of examples which superficially might seem to contradict this premise but closer examination of the evidence suggests that species have found routes over from habitats exceptional in the wild to ones made frequent by human intervention. The scale of food storage by animals increased logarithmically at the point when man became dominant in regions of environmental, seasonal stress, where storage formed an essential part of survival. Man left the trees only with lice (Buckland and Sadler, 1989) and has progressively acquired an expanding entourage of uninvited guests, against many of whom he wages a constant battle for survival (cf. Ordish, 1976). The impacts of typhus, spread by the body louse, *Pediculus humanus* (L.), and of bubonic plague, transferred from the black rat population by the flea, *Xenopsylla cheopsis* (L.), are well known (cf. Busvine, 1976) but less widely realised is the continuing tithe, in the past often considerably more than a tenth part, taken by insect pests during storage. The problem was sufficiently serious during the First World War for investigation by a special Royal Society of London Committee (c.f. Dendy and Elkington, 1919), and as recently as 1947, the United Nations Food and Agriculture Organisation (F.A.O.) estimated the World annual loss of cereals alone during storage to have been 10 % (Munro, 1966). By this date, mechanised sieving, to remove imagines and grains containing larvae, aeration in cold weather, to kill insects, and, later, insecticides (Ordish, 1976) were beginning to have some impact upon pest infestation but, equally, a worldwide trading network had converted what had once been local problems into global ones. The history of one lepidopteran pest provides an example. Despite its name, the Angoumois grain moth, *Sitotroga cerealella* (01.), was first noted near the west coast of France (Luçon) in 1734 by Réaumur (Sigaut, pers. com.), perhaps imported form South Africa, where its larvae breed in wild grasses. In warm temperate and tropical latitudes, it is able to attack the grain both in the ear and in storage and the moth caused recurrent famines, led to the abandonment of cereal cultivation in some areas and perhaps contributed to the unrest leading up to the French Revolution. It is now a common, cosmopolitan pest, particularly in heated grain stores. Lepidoptera are infrequent fossils and it is unlikely that the hypothesised origin can be substantiated. The more heavilly scerotized Coleoptera, however, are often preserved and theoretical models may be falsified as a result. The saw-toothed grain beetle was regarded by entomologists (e.g. Gigja, 1944) as being of New World origin, no doubt influenced by its Linnaean name, *Oryzaephilus surinamensis* (L.), which freely translates as the rice-loving (beetle) from Surinam. In 1956, dal Monte (1956) had recovered the species from charred grain from Herculaneum and Coope and Osborne (1968) published records from a Roman well at Barnsley Park, Gloucestershire ; the insect has since been found in Roman contexts on several sites (Buckland, 1981). Both biogeographic and archaeological conclusions may be modified by study of fossil insect faunas from suitable deposits and the grain fauna in particular is a singularly distinctive assemblage.

THE GRAIN FAUNA

The beetle fauna associated with stored cereals consists of an association of species which has not been recorded in natural habitats and one, the grain weevil, *Sitophilus granarius* L., has yet to be found away from synanthropic situations. Flightless, in contrast with its congeners, *S. oryzae* and *S. zeamais*, which in the Tropics may infest crops in the field (Krantz *et al.*, 1978), *S. granarius* must owe its present worldwide distribution to accidental transport by man from an original natural core area. The weevil is fairly catholic in its taste of stored products being recorded from wheat, rye barley, maize, oats, buckwheat, millet, chick peas and, less frequently, chestnuts, acorns and corn meal (Hoffman, 1954). Any might appear the primary host but archaeological records extend back to the third millennium B.C. in Egypt (Solomon, 1965) and the American crops are thereby precluded. The species does not thrive in the Tropics (Harde, 1984) and a warm temperate origin must be sought. The caryopses of wild cereals, the progenitors of the cultivated crops, may be too small for successful breeding, the larvae developing entirely inside the seed, and acorns might seem a more likely primary host, although breeding success rates therein are low. Zohary (1969) has described oak parkland with wild cereals as understorey in the Fertile Crescent and *S. granarius* may have made the move from the fairly eclectic stores of some rodents to those of man even before the adoption of the cultivation, rather than the collection of cereals. Its expansion westwards around the Mediterranean may have been in the company of the first agriculturalists, although the hypothesis has yet to be tested, the earliest record being from Minoan Crete (Jones, 1984). The species is cold hardy (Solomon and Adamson, 1955) but its northward progress would have been dependent upon the availability of suitably permanent stores and it may be significant that the earliest records in North West Europe are all within the Roman Empire (Buckland, 1981).

The other two major elements in the grain fauna, the saw toothed grain beetle, *Oryzaephilus surinamensis* (L.) and the flat grain beetle, *Cryptolestes ferrugineus* Steph., may have a different origin, since both are recorded from behind bark and in fungoid timber (Horion, 1960 ; Donisthorpe, 1939). Both are able to cope with meal and other ground starchy foods but have considerable difficulty with whole, dry grain unless it has been previously damaged. Mechanisation of crop processing and concomitant damage to the harvest has therefore led to increases, particularly in *O. surinamensis*, but, in the past, these species were considered to be secondary pests after *S. granarius* (Horion, 1960). Primary origins of infestation must remain an area for speculation but these natural occurrences would imply that the beetles may need the intermediary of a fungus for successful invasion of new habitats and the similarity between the under loose bark pabulum and damp grain, perhaps initially residues in granaries, may be rather closer than a superficial examination might suggest. Both species are able to disperse by flight (Hunter *et al.*, 1973) and the number of opportunities for fresh infestation of stored products in the past must have been almost infinite, without invoking the intermediary of the use of rotten timber for stores. In addition, as Woodroffe (1953) has shown, bird's nests can also provide a suitable staging post on the road to synanthropy. Such habitats seem also to be the primary ones for several other pests of stored products, but anthropochorous movements and the two-way transfer of individuals between natural and man-created pabula makes any attempt to suggest core areas for the origin of this species association hazardous and the community may go back to the first farmers in the Fertile Crescent. *O. surinamensis* had certainly reached Egypt by 1345 B.C. occurring in the tomb of Tut'ankhamun (Zacher, 1937), whilst *S. granarius* had arrived by at least one thousand years before (Solomon, 1965), *Cryptolestes ferrugineus* earliest association with man currently is no earlier than Roman Britain (Osborne, 1971) and it may be that this species was added to the list of pests of stored products from the European Old Forest Fauna (cf. Buckland, 1979), during later Prehistory.

The apparent initial dependency of *O. surinamensis* and *C. ferrugineus* on damage from *S. granarius* in grain stores implies that the association may have been accidently dispersed by man as a unit. It is perhaps relevant that the earliest European records are again Roman (Buckland, 1981). Although relatively cold hardy and able to overwinter in unheated stores (Solomon and Adamson, 1955), *O. surinamensis* is unable to complete its development at temperatures below 18° C and does not thrive below 22° C (Howe, 1965). This imposes a northern limit on its natural distribution and its presence in archaeological deposits in Northern Europe may be taken as a fairly safe indication of the proximity of stored cereals. In Iceland, where conditions are particularly severe and the settlement pattern dispersed, it is unlikely that the grain fauna would have been able to maintain populations in the small, poorly insulated grain stores of subsistence farmers, and the presence of *O. surinamensis* has been used to argue for imported, rather than locally grown cereals at one farm during the medieval period (Sveinbjarnardottir, 1983). Other factors than simply insulation from the outside cold are critical to synanthropic insects for survival. Both damp and weevil infestation lead to heating in grain, a problem often guarded against by aeration, a technique known to the Romans (Rickman, 1971), and it is these hot-spots which allow pest species to multiply at an alarming rate to the extent that the entire contents of a store may be rapidly spoiled.

The problem of temperature thresholds sufficiently high to maintain breeding communities is even more apparent with a number of the other cereal and cereal product pests. The flour beetles, *Tribolium* spp., require heated buildings throughout the year outside the Mediterranean zone, although populations may be sustained for short periods by localized heating within the stored product. Their dispersal must be later than the development of an organised grain trade and suitable, presumably urban central places, where food resources were sufficiently concentrated. The first records of *Tribolium* species outside Egypt are again Roman (Buckland, 1981). The taxonomic arguments for the origins of the several species, all of which may perhaps be ascribed to a primary under bark « white rot » habitats, have been discussed in the light of the fossil record, including finds from Egyptian tombs (*ibid.*).

Several species are more associated with grain residues than with causing damage to the actual stored commodity, although, in Antiquity, it is probable that the two habitats were often less discrete. Amongst the spider beetles found in synanthropic situations, the golden spider beetle, *Niptus hololeucus* Fald., is recorded from late medieval deposits in the Rhineland (Cymorek and Koch, 1969) and from the Roman sewer in York (Buckland, 1976b), yet, although a fairly conspicuous insect, it does not appear to have established itself in western Europe until the middle of the nineteenth century and both records require confirmation. Its larvae develop in starchy materials, particularly grain and chaff residues (Harde, 1984), and, since the imagines are flightless, it is likely to have been distributed via the grain trade, perhaps from primary habitats on the north side of the Black Sea (Buckland, 1976a) ; the species is now cosmopolitan. The more sour residues, beneath the boards of granaries, may include an eyeless, flightless beetle, *Aglenus brunneus* (Gyll.), which, if not phoretic, must rely entirely upon man for its dispersal. Perhaps initially an insect of a once virtually continuous habitat, the litter layer on the undisturbed forest floor, its earliest fossil record may be late in the British Iron Age, if not early Roman (Robinson, 1979) and it occurs in later Roman deposits (Kenward, 1976). The foul conditions of medieval urban floors and rubbish deposits, heated by their own decay, provided a further suitable habitat and the beetle is almost a zone fossil in Anglo-Scandinavian York (Kenward, 1975) and has also been recorded from a number of other urban sites. If, as Kenward (in Hall *et al.*, 1983) has argued, the grain fauna is absent from the Viking age North, continuity of habitat or reintroduction remains an interesting problem.

The bias towards the Roman period in occurrences of the grain fauna may be merely an artifact of the availability of samples for research. As well as the relatively numerous British records (Buckland, 1981), elements are known from the Roman Rhineland (Koch, 1971) and from Herculaneum (dal Monte, 1956), the latter providing a firm date of A.D. 79 for the association of *S. granarius* and *O. surinamensis*. In the Mediterranean World, the process of synanthropy must go back much further but suitable deposits have yet to be examined. Northwards, the problems of temperature and habitat continuity for the insects become more acute and it is not surprising that it is in association with the Roman military machine that the fauna appears. Dispersed settlement patterns and paucity of large centralised stores would have severely limited both dispersal and continuity of grain pest faunas in the pre-Roman Iron Age and, later, outside the Empire. Similar problems would have attended the collapse of the Empire during the fifth century A.D., and the grain fauna may have withdrawn to reservoirs in the Mediterranean World until the rebirth of towns in the North from the eight century onwards. The Roman trading network covered most of the then known world (cf. Wheeler, 1954) but, in the less warm climates, size of stores, quantities and relative permanence are also important for the fauna and it is the provisioning of large armies of invasion and occupation, requiring the shipment of large amounts of grain, and other commodities, which provided the springboards to pest invasion. During the first century A.D., the agricultural writer Columella and the natural historian Pliny the Elder were aware of the problems for the farmer caused by the grain weevil (*Curculio*) and suggest a number of inevitably ineffectual remedies (White, 1970). The extent of collection and trade networks in the Roman period were such that at least part of the grain fauna has been recovered from all suitable sediments wich have been examined (Buckland, 1981). Each fort had its granary, which, from its initial stocking is likely to have had some storage pests, which annual cleaning could only reduce and not eradicate. These provided the reserves from which all other stores of sufficient size to provide the necessary heat or insulation could have been populated. Whether the armies of a Rameses, Darius or an Alexander were similarly beset with an entomological tithe is presently unknown but the grain fauna must have had a significant impact upon both military and civil populations. The integrated market economy, with its strong ties to the provisioning of the frontier garnisons, led to the accidental dispersal of other species than the grain pests and the parallels with west European impact on New World biota (Lindroth, 1957) are instructive. Many introductions were casual, with little impact at the destination and several beetles are first recorded from Britain in the Roman period. One, the large Carabid, *Zabrus tenebrioides*, from the Roman villa at Empingham in Rutland (Buckland, 1986) may be a serious pest of cereals in the field in mainland Europe. The process of floral and faunal redistribution which threatens us with a world dominated by European crops and weeds received its first major input during the Roman Empire.

Although there are periods at least in northern Europe when pest infestation of stored grain may have been a minor intermittent problem, some livestock in their food would have had to have been accepted by the majority in Antiquity. The problem could be reduced by sieving, when the lighter grains containing weevils larvae would tend to accumulate on the top and, as Joseph Banks described, in 1769, heating would drive the fauna out of biscuits (Banks, 1797, quoted in Buckland, 1981). It is, however, only our modern, perhaps too hygienic society that views the occasional insect, the nutty bit in wholemeal bread, with consternation. At the present day, the stored product domestic pest is most likely to be the biscuit beetle. *Stegobium paniceum* (L.), which has been a constant companion at least since the Bronze Age (Osborne, 1986). In Antiquity, the choice of insect was wider and the tolerance greater. In a practical experiment, Osborne (1983) has shown that insect pests pass through the digestive system relatively undamaged and may thereby become incorporated in archaeological deposits. The consumption of weavily bread or porridge is suggested by finds from the ditch of the Roman fort at Bearsden in Scotland (Dickson *et al.*, 1979), and the scatter of grain pests in the York Roman sewer (Buckland, 1976b) is better interpreted in terms of an input from human fæces, rather than as strays from a nearby granary, although the large number of the essentially Mediterranean ant *Hypoponera punctatissima* (Rog.) in the channel indicate the proximity of a heated building.

There are limits to tolerance in levels of insect infestation in foodstuffs, beyond which the grain or flour becomes inedible as a result of the concentration of uric acid and microflora. Such material may be fed to domestic stock but soon becomes toxic. The point is strongly made by an indictment at Nottingham in 1432, when Thomas Sharp was charged with selling malt so raw, recked and damaged with weevils that it killed the hogs, hens and capons which are fed upon it (Salzman, 1923). The problems of containing pest species levels were not entirely solved until the middle of the present century and they form the basis of a multi-million pound chemical industry. Without such killing, some would say overkilling, the producer and trader had two partial remedies : pit storage and the burning of residues. Reinfestation from residues remains a serious problem, usually tackled by a liberal use of insecticides (Coombs and Freeman, 1955) and, in the past, careful cleaning of stores could only reduce the problem. Many of the burnt grain deposits and scatters of charred grain from excavations must owe their origin to the disposal of infested residues (Buckland, 1982 ; Osborne, 1977). Sherds of pottery, tempered with chaff, from one Bronze Age site in the Aegean included casts of *Sitophilus granarius* accidentally incorporated (Osborne, unpubl.). Where the level of insect attack within the building had become intolerable, the only effective courses of action available were changes of use and removal of fresh foodstuffs to an alternative building, preferably some distance away, or the more drastic measure of burning the granary down. The latter seems to have been the solution on at least one occasion in Roman York (Kenward and Williams, 1979) ; in the past, such deposits were often interpreted as the result of enemy action (Buckland, 1982). Not all charred grain need be the outcome of the destruction of tainted residues. Efficient drying will reduce the possibilities of secondary infestation in seed corn and storage in the glume may also be beneficial. Drying may be taken to the extent of parching in grain for consumption which further protects the grain. The frequency of corn drying kilns in regions where the climate should render them an unnecessary luxury might be considered in this additional light.

An alternative approach to the problem is provided by pit storage. Early this century, Dendy and Elkington (1919), led by reports of effective underground storage in Malta and India, advocated large scale storage in underground silos, where, as the grain respires the concentration of carbon dioxide eliminates the insect fauna (Hyde and Oxley, 1960). Pit storage was widespread in Antiquity and has been the subject of much discussion and some experimentation (cf. Reynolds, 1974). Although the insect aspect has been hitherto neglected by archaeologists, the historian François Sigaut (1978) has considered the evidence in some detail. Halstead (pers. comm.) has pointed out that the technique was employed by Greek farmers until World War II and they were aware of its importance in controlling insect pests. Experimental work has concentrated upon grain but it should be noted that pulses might equally be stored in pits and the so-called pea-weevils, the Bruchids, can be equally destructive of stored products, although primary infestation actually occurs in the field (Harde, 1984). Burleigh and Southgate (1975) note a previously undescribed species of Bruchid from Egyptian lentils of ca. 215 ± 48 B.C. but other records are either much more recent (e.g. Keepax *et al.*, 1979) or less clearly synanthropic (e.g. Shotton and Coope, 1983). Species able to attack pulses in store, such as *Acanthoscelides obtectus* (Say), may be more recent introductions to Europe, this species occurring in horsebeans (*Vicia faba*) taken to Spitzbergen (Svalbard) by seventeenth century whalers (Van Wijngaarden-Bakker and Pals, 1981) ; its origins are probably North American (Dillon and Dillon, 1972).

The use of pits for storage is clearly restricted both by substrate geology and water table and maps of its occurrence (e.g. Piggott, 1958) may be as much a reflection of this as cultural constraint upon storage methodology.

Urbanisation and concentration of resources in fewer hands lead to economies of scale and pit storage ceases to be a viable option, despite increased losses to insect pests. It is unlikely that storage in large jars (*pithoi*) would reduce pest infestation, as the relatively porous nature of the fabric would allow the grain to breathe, although relative humidity, temperature and volume are also critical (cf. Munro, 1966) ; the problem requires investigation by practical experiment. Large granaries are a feature of the Ancient World from Harappa (Wheeler, 1966) to the northern frontiers of Rome (Gentry, 1976) and there can be little doubt that the use of wood, rather then ceramic, storage bins, with a multitude of suitable hibernation or aestivation places, would have exacerbated any pest infestation problem. In northern Europe, scale is all important and the pest problem was apparently a Roman introduction. In the Mediterranean World, the problem was perhaps containable at the local level, becoming significant only with increasing urbanisation and the need to equip large standing armies.

A final *caveat* is critical. Attempts to calculate population and land under cultivation in Antiquity are widespread in the archaeological literature (e.g. Applebaum, 1972) and such modelling has become an increasing occupation among armchair theorists. The practicalities of losses to insects in storage have not been considered (cf. Buckland, 1978). It is salutary to note that Hoffman (1954) suggested that 5 % of French cereal production before the last World War was lost to one pest, *Sitophilus granarius*, alone. What figures should be played with overall for past cultures ? The impact of large scale loss may be wholly random, contained in some years but leading to starvation in others. The introduction of a new pest may have short term disastrous results. The case of the Angoumois grain moth has been considered above but the case of *Phylloxera*, introduced from America to the French vines (Ordish, 1972) and the Colorado beetle, from a similar source (Elton, 1958) are equally instructive. Was the impact of *Pax romana* upon North West Europe one of increased storage losses leading to a temporary population check, followed by adjustment by increased land under cultivation or was the problem purely an initially military logistical and then urban one ? The possibilities for hypotheses are no doubt endless and Ball's Law, the less the evidence, the stronger the hypothesis might reasonably be invoked.

CONCLUSION

Several attempts have been made to write the annals of insect impact upon human history (e.g. Busvine, 1976 ; Cloudsley Thompson, 1976 ; Ordish, 1976). All lack the archaeological and palaeontological dimension, largely as a result of the paucity of research into fossil synanthropic faunas, particularly in the Mediterranean region. It is hoped that this discussion has at least highlighted the potential of such studies.

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