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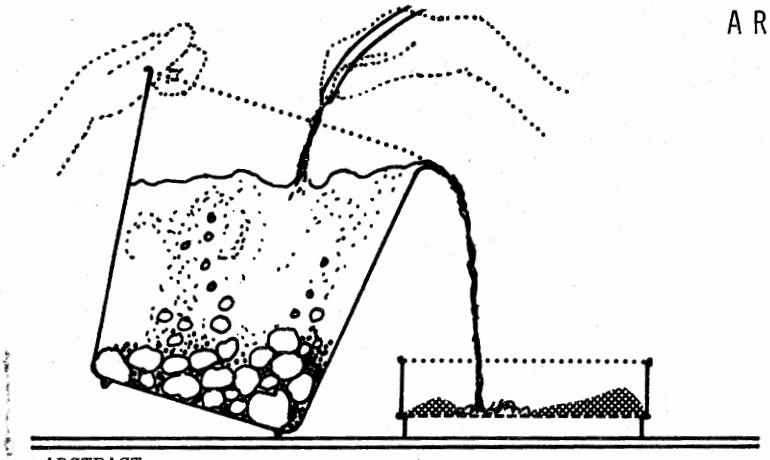
A TESTED SET OF TECHNIQUES FOR THE EXTRACTION OF PLANT AND ANIMAL MACROFOSSILS FROM WATERLOGGED ARCHAEOLOGICAL DEPOSITS



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ABSTRACT

The principles and methods of extracting and concentrating plant and animal macrofossils from waterlogged archaeological deposits are briefly reviewed. Bulk-sieving (carried out on site), the extraction of plant macrofossils using a sieve-bank, and paraffin-flotation for insects are each described. Accounts designed to provide sufficient practical detail to permit successful application of the methods are given.

Keywords

ENVIRONMENTAL ARCHAEOLOGY, PALAEOECOLOGY, METHODOLOGY, WATERLOGGED DEPOSITS, PLANT MACROFOSSILS, SEEDS, INSECT REMAINS, BEETLES, BONES, SNAILS, EXTRACTION TECHNIQUES, WATER-SEPARATION, ON-SITE METHODS, BULK-SIEVING, PARAFFIN-FLOTATION, CONCENTRATION, RECORDING.

Introduction

Biological remains from archaeological sites are examined for three principal reasons: firstly, for their intrinsic interest to biologists and ecologists; secondly, in order to reconstruct human diet and activity; and thirdly, to reconstruct past environments, both local and regional and including human living conditions. A detailed discussion of the interpretative value of each of the groups of macrofossils which may be encountered is beyond the scope of this account, but to date animal bones, plant remains, snails and insects have been the most extensively investigated.

The present account is mainly concerned with arthropod remains, plant macrofossils and small bones, but some other groups are briefly considered. The set of techniques which has been found most satisfactory for waterlogged deposits of all kinds, and which is employed at the Environmental Archaeology Unit (EAU), York, is described in detail. While this account may occasionally appear to state the obvious, long experience in teaching the methods has underlined the need for a precise description. Tests demonstrating the efficacy of the techniques will be outlined elsewhere (Jones et al., in prep.).

Whatever the purpose of the investigation, if anything more than a mere catalogue of common species is required it is desirable to examine very large numbers of specimens. There are two reasons for this: firstly, to obtain a reasonably representative sample of the assemblage in a deposit, and secondly, to provide numbers large enough for statistical manipulation of the data (see, for example, Kenward, 1978; in prep.; Hall and Kenward, in prep.). This holds true whatever group of organisms is being considered. Assemblages of 100 individual insects and 200 seeds from a single sample are probably the minimum for useful interpretation, although assemblages several times larger are preferable, and interpretations should ideally be based on groups of samples rather than single ones.

The concentration of insects and seeds in waterlogged deposits varies enormously, and 5 g to 10 kg or more of sediment may be needed to provide an adequate assemblage; typically, samples of 0.5 to 1 kg for seeds and 1 to 3 kg for insects are found to be suitable. The sample collected on site must, of course, allow for the worst contingency and should be at least 5 kg, but ideally over 10 kg. Samples of 10 kg will generally provide sufficient material for a variety of analyses. Sampling and subsampling strategies are complex and subject to many variables, and will be discussed elsewhere (Kenward et al., in prep.; Topsey et al., in prep.), but it is worth remarking here that single bags of sediment may not be representative of a large context (Hall et al., in prep.). There is much confusion as to the kinds of samples required for the investigation of particular groups of organisms; in the hope of ameliorating this, suggested sample sizes are given in Table 1, together with a standard nomenclature found useful at York.

Some common extraction methods

Since large quantities of sediment and large numbers of samples must generally be processed to obtain adequate biological material, some technique to reduce the labour of extracting plant and animal remains is necessary. The simplest but most impractical way of recovering biological remains is sorting the raw sediment. It would be quite unreasonable to employ this method for a serious study, for it is immensely time-consuming and, since most fossils are coated with sediment, the vast majority would be overlooked. Almost all successful methods therefore involve sieving off

TABLE 1. SAMPLE TERMINOLOGY

Type of sample	Analysed for	Sample sizes and notes
"Micro-sample"	Pollen, diatoms, protozoa spores, intestinal parasite eggs, cladocerans, ostracods, copepods	These samples are normally taken in columns or sets, specifically for analysis of one group, but may sometimes be taken from the middle of blocks of sediment collected as "biological samples". One or a few grams are usually adequate; if larger samples are required, the concentration of fossils is probably too low for significant interpretation, except for crustaceans, where a few tens of grams may be needed.
"Biological sample"	Mites, insects, seeds, fruits, mosses, molluscs (freshwater and terrestrial snails)	These groups would normally be taken from sub-samples of a normal biological sample of 5 - 10 kg. Weights for each group: mites - 0.5 - 1 kg, insects - (0.005-) 1 - 3 (-10) kg, seeds and fruits - (0.1-) 0.5 - 1 (-5) kg, mosses - depends on type of deposit; usually sampled with fruits and seeds, molluscs (terrestrial and freshwater) - 0.5 - 1 (-5) kg.
"Soil sample"	Chemical and physical soil analysis	0.5 - 1 kg.
"Bulk sample"	Shellfish, small bones, large seeds and fruitstones, wood, larger charred material (especially grain)	c 15 - 150 kg (- whole context) (and samples of spoil should also be processed to check efficiency of recovery by hand-picking): N.B. does not provide a complete assemblage of groups including material smaller than 1 mm.
"Hand-picked sample"	Large bones, shellfish, wood (also occasional caches of seeds, moss, puparia, charcoal etc.)	Whole site normally "processed" by trowelling.

the fine organic fractions. This makes the fossils much more easily recognizable, permitting efficient sorting. The technique is widely employed, and the authors regard the use of a graded bank of sieves as the most satisfactory means of extracting plant macrofossils and snails. The same technique can be employed for insect remains, but it is too time-consuming as larger samples are generally required and insect remains are often hard to recognize amongst plant debris, especially charcoal. A number of methods have been tried, but the only one considered to be practicable in terms of reliability and cost-effectiveness is paraffin-flotation. This technique has been developed from methods originally devised for the extraction of terrestrial arthropods (Southwood, 1966) and was adapted for work on Pleistocene insects (Coope and Osborne, 1968; Shotton, 1970). The method has been described by Speight (1974) as 'strangely capricious', but this is directly at variance with experience at Birmingham and York. It is considered that it has the virtue of being cheap, straightforward and trustworthy. However, it has been found that students who have attempted the method without practical instruction, and with a poor understanding of the principles involved, have often met with failure. For this reason, a detailed description of the standard method employed at the EAU will be given; care has been taken to include all the nuances which can make the difference between success and failure. The method has been applied to a great variety of sediments and the results of tests will be presented elsewhere (Jones et al., in prep.).

Other techniques for concentrating biological remains vary in their value. The complicated froth-flotation machines are, in the authors' view, unsuitable or unnecessarily elaborate for most deposits from temperate regions, although a number of workers have found them useful when dealing with soils with a very low organic content, for example in the Near East. However, the use of a bulk-sieving apparatus on site for processing large samples is regarded as an essential component of excavation. It is invaluable in the recovery of small artifacts overlooked by excavators but, more importantly, for sampling small bones (particularly those of fish), larger molluscs and some larger insect and plant material, for example fruitstones. Such remains are generally too thinly distributed to be retrieved in useful numbers from "biological samples". However, it must be emphasized that many small remains are lost during bulk-sieving and that the fossils recovered are a biased sample (Jones et al., in prep), so that it is completely unsuitable for detailed work on plant macrofossil and insect assemblages. Equally, bulk-sieving in the field is unavoidably contaminative, both from one sample to another and from modern plants and invertebrates. Dense medium separation and the use of strong reagents like caustic soda and mineral acids, have limited value except in special circumstances. Dense medium separation has been used successfully for extracting mites (Denford, 1978); the efficiency of paraffin-flotation for recovering mites requires further consideration. The paraffin-acetone method (Kenward, 1974) can be used for very small arthropod remains, but this technique has not been adequately tested. A method of extraction involving a greased belt has been described (Speight, 1973); although the

present authors have not used this device, it appears to be unnecessarily complicated compared with the proven paraffin-flotation process and, moreover, to judge from the description, it is unlikely to be suitable for richly organic deposits.

A standard approach to the recovery of biological remains

The remainder of this paper describes the methods used at the EAU for the processing of biological samples. It varies in the amount of detail given, a fuller account being provided where difficulty is likely to be experienced.

Plant macrofossil and insect extraction is typically carried out on pilot samples of 1 kg and further sub-samples processed as required to provide sufficient fossils for interpretation. Snails are generally recovered from a separate sub-sample, using methods described by Evans (1972), but may conveniently be retrieved from the same sub-sample as plant macrofossils or insects, using banks of sieves. In either case, disaggregation must be gentle to prevent damage to the fragile shells, and, of course, no acids should be used.

Hand-picking on site

Biological remains are often recognized during excavation and recorded and sampled in the same way as small finds. Caches of seeds, large beetles, groups of fly puparia and of small bones may be treated in this way, whilst large bones are typically processed as loose finds, bagged by context in the same way as pottery. A critique of this method of recovering bones is beyond the scope of this paper (but see, for example, Uerpmann, 1972, and papers in Cherry et al., 1978).

Bulk-sieving

Considerable confusion has arisen concerning the terminology applied to on-site methods of processing large quantities of soil for small bones, large seeds and charred grain, artifacts and the like. The authors prefer to adopt the terms 'bulk-sieving' or 'water-separation' for the method described below (which relies primarily on water currents for separation) and the term 'bulk sample' for the material processed by it. The expression 'flotation machine' is reserved for apparatus using air bubbles or organic liquids in addition to water currents (for example the 'Cambridge Machine', Jarman et al., 1972).

The application of bulk-sieving to the whole of any archaeological context likely to contain remains over 1 mm in diameter might be viewed as a routine excavational technique. However, in practice bulk-sieving is seldom done, for a variety of reasons including traditional bias towards large artifacts and structural remains and the time necessary to carry it out and to sort the resulting material. Experience at York suggests that not only are large amounts of useful biological material recovered by this method, but that significant quantities of pottery, small finds and technological products like slag may also be retrieved (Jones et al., in prep.). Bulk-sieving can be applied in two ways, which should be clearly distinguished. Firstly, bulk samples representative of a context may be processed to give a reliable sample of its inclusions, both biological and artifactual. Such bulk samples should, of course, have nothing removed from them prior to sieving, and the quantity of material processed should be recorded. Secondly, the apparatus can be used to retrieve small objects and biological remains from the whole of the trowelled spoil from individual contexts; it has been shown that spoil often contains much material overlooked using traditional excavation techniques. Bulk-sieving also provides an opportunity to make a detailed examination of the gross composition of a deposit and its large and small-scale variations.

A suitable apparatus for bulk-sieving, modified from that described by Williams (1973), is shown in Figure 1. Soil is suspended upon a one-millimetre mesh within the tank and a current of water is run through the soil, carrying off light material such as wood and charcoal fragments. Small mineral particles fall through the mesh into the tank, which is periodically emptied. The water flow is directed onto a sieve (also one-millimetre mesh) where the floating material ('flot') is collected. The clean residue on the mesh, and the flot, are bagged separately after drying and may then be sorted in the laboratory.

There is, of course, no reason why bulk-sieving should not be carried out in the laboratory, providing a suitable sump is available.

Operation of the bulk-sieving apparatus

A Apparatus: A bulk-sieving tank (Figure 1); 1 mm mesh sieve, about 30 cm diameter; 1x1 m sheet of 1 mm aperture nylon mesh; plastic labels; black, spirit based waterproof felt-tip marker; recording sheets; drying trays; polythene bags (*c*.60x45 cm); a supply of cold water; sump. A recycling pump and water-heater can readily be fitted to the apparatus, reducing the volume of water required and making operation less unpleasant in cold weather, although a settling tank will then be necessary.

B Preparation: The tank, mesh and sieve are thoroughly cleaned, the hose is connected to the inlet pipe and the drain plug closed securely. While the tank is filling with water, the wire support for the nylon mesh is positioned. The mesh is secured into the weir by the V-shaped rod and spring-clips used to anchor it to the rim of the tank. It is necessary to pleat the mesh to accommodate the bulk of soil. The flot sieve is positioned beneath the weir and a steady flow of water established.

C Recording: A recording sheet (Figure 2) is completed and four labels are marked with the site code and context number. A separate code is used to distinguish the residue and flot (R and F respectively are used at York).

D Operation: When water is flowing steadily through the sieve, a bucket of soil is introduced onto the nylon mesh, care being taken to avoid losses through splashing. The lumps of soil are gently disaggregated by hand, so as to minimize mechanical damage to fragile remains. Floating debris are encouraged into the flot sieve by generating ripples across the water surface. During washing, notes are made of the nature of the sample, including the size and types of stones; particular attention is paid to any possible modern contaminants, for example airborne propagules or insects. The process continues until all sand, silt and clay have been washed through the nylon mesh.

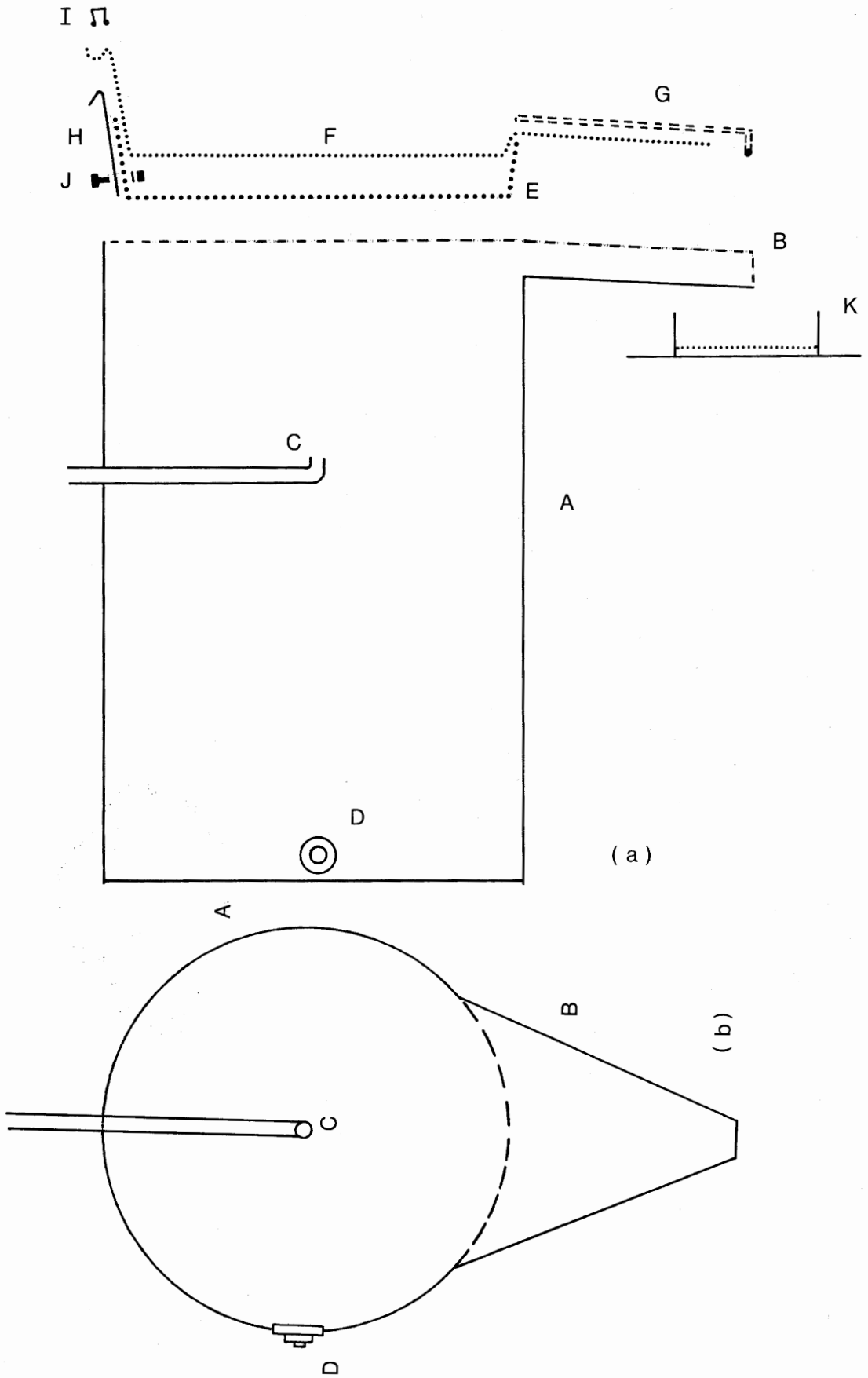

Figure 1. (a) Bulk-sieving apparatus: 'exploded' vertical section. (b) idem: plan of tank. A - 50-gallon oil drum; B - weir welded to drum; C - c. 2 cm. diameter inlet pipe; D - 5 cm. diameter drain plug; E - c. 2 cm. weld mesh, supporting; F - 1 mm. nylon mesh; G - V-shaped rod, holding F in position on weir; H - steel straps supporting E; I -3 cm. fold-back clips holding F to rim of drum; J - bolt and washers clamping H to E; K - flot sieve, 1 mm. mesh. Scale: sieve diameter = 20 cm.

The inlet pipe should enter the drum approximately two-thirds of the way up the side; the support mesh, when positioned in the tank, should hold a full bucket of soil totally submerged. There are no other critical features and tanks are readily improvised.

N.B. See also bulk-sieving record for this context.

ENVIRONMENTAL ARCHAEOLOGY UNIT — LABORATORY RECORD SHEET — UNIVERSITY OF YORK

SITE NAME	SITE CODE	AREA	CONTEXT NO.	SAMPLE NO.	SUBSAMPLE NO.
MIDDEN STREET	1979.1	IV	1760	22	/1

WASHED BY	DATE	TYPE OF FEATURE	SIZE OF WHOLE SAMPLE: Very large (Large) Medium Small Very small
A.B.	1-1-79	lower fills of well	

WEIGHT OF SUBSAMPLE	APPROX. VOLUME BEFORE WASHING	APPROX. VOLUME AFTER WASHING
1 kg	1/4 bucket	1 sieve full

PREWASH NOTES: Black, peaty silt; some wood fragments to about 3 cm. in length. See files for Soil Description Sheet. Do internal and external colours vary - How?

Dry (Moist) Wet Waterlogged

TREATMENT: Washed in hot water; sieved to 300 μm; Boiled. Resistant lumps.

N.B. Sort float for seeds.

PARAFFINED BY: A.B.

WASHOVER: ~~$P_1 f_1 f_2 f_3 f_4$~~ ~~$P_2 f_1 f_2 f_3$~~ ~~$P_3 f_1 f_2 f_3$~~ $P_4 f_1 f_2 f_3$

WASHING NOTES: Bulky residue after sieving. Sieved to 2, 1 mm, 500, 300 μm for plant macros.

FLOAT SORTED BY: C.D. — NUMBER OF DISHES: IIII III

FLOAT SORT NOTES: Some worm egg capsules; fly puparia abundant; some mites. Preservation not good. Seeds added to residue sort tube.

RESIDUE SORTED BY: C.D.

(Sorted wet) Sorted dry

RESIDUE SORT NOTES: Seed assemblage quite rich; lots of Conium — all counted but not all picked out.

EVIDENCE OF CONTAMINATION: None

SMALL FINDS, ETC.: Some pot fragments: 1 min — SENT TO: E.F.

Components of Sample	Float Sort	Residue Sort	Bagged	Comments
Pottery		✓	✓	
Metal				
Glass				
Brick/Tile		✓		Frags.
Mortar/Plaster				
Stone		✓		Chips
Coal		✓		
? Slag		✓	✓	confirmation??
Wood		✓		? C14 — det.?
Charcoal				
Carbonised grain		✓		Tube - not much.
Seeds	✓	✓		Tube - abundant
Nutshells	✓	✓	✓	
Fruit stones	✓	✓	✓	Abundant
Moss				
Mammal bone		✓		Frags.
Small mammal bone				
Fish bone		✓	✓	
Bird bone				
Leather		✓		Scraps
Insects	✓			Mostly pale.
Fly puparia	✓	✓		Lots; all the same; left in.
Fly pupal fragments	✓			
Mites	✓			left in; 2 or 3 kinds; rather rare.
Cladocera				
Worm capsules	✓			1 kind; abundant.
Snails				
Shell fish		✓		Oyster frags.
Eggshell				
Amber		✓	✓	To Finds Dept.

	Comments	Exam.	Noted	Written up	Stored at
Seeds	List in files.	✓	✓	✓	
Snails					passed to museum
Shellfish	ff discarded to residue	✓	✓		
Insects	Too few for analysis; needs 10 kg.	✓			
Mammal bone	Leave.	✓			
Fish bone	To G.H.				

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Figure 2. (a), (b) Dummy copy of Laboratory Record Sheet used at EAU, York. The sheet is also used on site for recording bulk-sieving.

E Removal of the flot: The flot sieve should be emptied when about half-full, to avoid blockage and subsequent spillage. If the sieve needs emptying before a bucketload has been completely washed, the V-shaped rod which clips the mesh to the weir is removed and lodged so that the portion of mesh lying on the weir is raised free of the water, thereby preventing further flow of flot. The flot sieve is removed, briefly drained to remove excess free water, emptied into a polythene bag or onto a drying tray, and the bag or tray is labelled. When all the material has been processed and the flot removed, the sieve is washed in clean water.

F Removal of the Residue: The spring clips are removed from the rim of the tank, and the mesh gently agitated to free any material trapped by surface tension. The V-shaped rod is removed and the four corners of the mesh gathered together. The mesh is removed from the tank, with a pause to allow free water to drain from it, and the residue is then tipped onto a drying tray and two labels placed with it. When all the material from a context has been washed, and the residue and flot removed, the tank is emptied by opening the drain plug, and the nylon mesh shaken clean. Record sheets are checked, with particular attention being paid to the volume or weight of material processed.

Plant Macrofossil Extraction

The most satisfactory technique for concentrating plant macrofossils from organic archaeological deposits involves disaggregation and separation in a graded bank of sieves. Methods of extraction described by Dickson (1970) for natural deposits will be useful in certain archaeological situations (for example fen and bog peats) but most sediments encountered in towns are better treated by the technique given below. Some workers have used paraffin-flotation for the recovery of plant macrofossils but it must be emphasized here that the flot from paraffin-flotation, by itself, does not provide an adequately representative assemblage of seeds and other plant remains. If paraffin-flotation is to be used to extract insect remains from the same material, it is essential that the sample is sorted by the method outlined here before flotation, or that both flot and residue are sorted for seeds.

Some aspects of the extraction of mosses, remains of which are frequently present in samples, are discussed by Williams (1976).

A Apparatus: Drainer with sump (Figure 3); a lipped bucket, *c.*10 l capacity, plastic or metal; 300 micron mesh-aperture brass sieve (rim crevice must be filled with solder and label removed to prevent cross-contamination, see Figure 4); bank of brass sieves of mesh sizes 500 micron, 1 mm, 2 mm, 4 mm, etc. (Figure 5), as dictated by the sample (rim crevices likewise sealed and labels removed); a supply of hot and cold water; 3 x 1" (7.7 x 2.6 mm) plastic stoppered glass vials; labels (in pencil, on card); alcohol-glycerine-formalin solution (approximate porportions are 60 parts glycerine: 30 parts industrial methylated spirit: 2 parts 40% formalin).

B Preparation: All apparatus must be cleaned scrupulously, using hot water, detergent and a stiff scrubbing brush. A suitable quantity of sediment for processing is weighed out, and details of its lithology recorded, together with site code, context and sample numbers etc., on a laboratory processing sheet (Figure 2). The bucket should also be labelled with site code and sample number.

C Operation: The sample is placed in the bucket and hot water added.

The sediment is disaggregated by being gently agitated by hand and, when it has begun to break down, the bucket is tilted over the 300 micron-mesh sieve so that a stream of water can flow over the sample and onto the sieve. The process is continued until little or no more fine material passes the mesh, and the sample is thoroughly disaggregated. In extreme cases, for example compressed peat, samples may be soaked in 5 - 10% sodium hydroxide solution for days or weeks prior to processing (see also p.11 below). Boiling in water or mild reagents may also assist disaggregation. Next, the residue is returned to the bucket and the bank of sieves set up with the 300 micron-mesh sieve at the base. The residue is placed in the top sieve and washed down the column with a gentle stream of water. Care must be taken to avoid loss of material from the top sieve by splashing, or from lower sieves if blockage of the mesh and overflowing occur. It is desirable that the sieves be as tight-fitting as possible, to minimise this latter problem. The use of a large range of sieve sizes also facilitates rapid separation and, subsequently, sorting. A sprinkler nozzle may be fitted to the rubber hose, producing a diffuse, gentle stream of water. If there is a large mineral content the organic fraction may be extracted by the 'washover' technique described below (p.11), before column-sieving.

D Sorting: When separation into fractions is complete, the contents of each sieve are sorted a little at a time under a low-power binocular microscope (x12.5), the material being spread in water on a glass or white ceramic dish. Remains are picked out using fine watchmakers' forceps. Some practical aspects of sorting for plant remains, in particular the sorting of fine fractions, will be dealt with elsewhere (Jones et al., in prep.).

E Storage: Seeds and other plant remains picked out for identification are best stored in alcohol-glycerine-formalin solution (AGF), in plastic-stoppered glass vials, enclosing a label written in pencil on white card or paper. The tube may also be labelled externally, though alcohol-soluble media are to be avoided.

Insect extraction

The method of paraffin-flotation described here has been refined from that used on archaeological material by P.J. Osborne at the University of Birmingham. It is reliable for the extraction of almost all insect and other arthropod remains, with the exception of dipterous (fly) puparia, strongly calcified cuticle (for example, woodlice), and charred or mineralised fossils. If these are to be recovered, the methods described above for plant macrofossils should be employed. Paraffin-flotation is carried out on 1 kg subsamples at the EAU; these are of a convenient size for handling.

A Apparatus: A supply of hot and cold water; drainer with sump (Figure 3); lipped bucket (*c.* 10 l capacity), plastic or metal; 20 cm diameter 300 micron-mesh aperture brass sieves with rim crevice sealed and label removed (Figure 4); 5 - 10 l stainless steel boiling beaker (aluminium is suitable if disaggregating reagents are not to be employed); boiling ring; washing soda (hydrated sodium carbonate); liquid detergent; domestic paraffin (kerosene; a paraffin conforming to

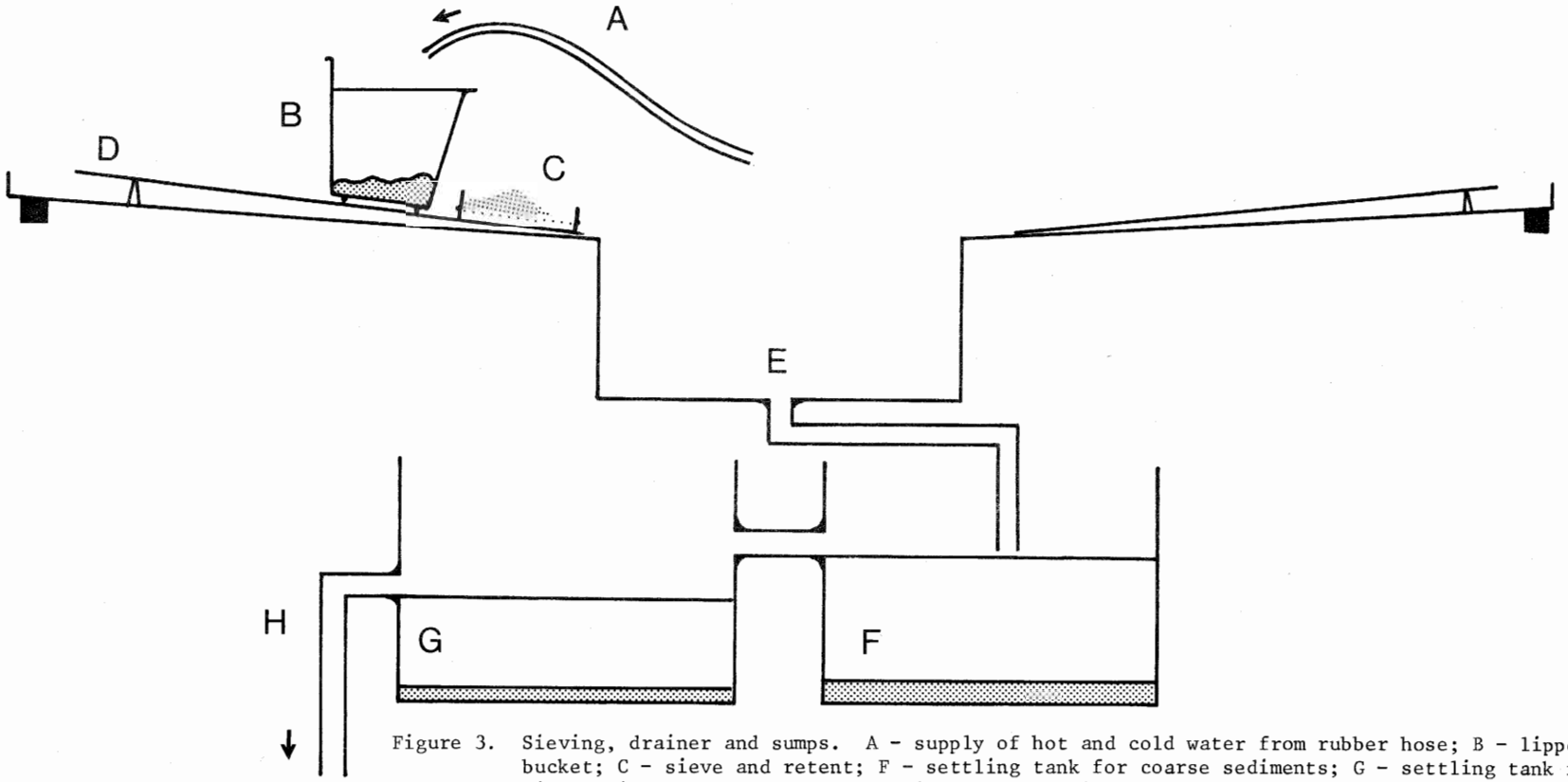

Figure 3. Sieving, drainer and sumps. A - supply of hot and cold water from rubber hose; B - lipped bucket; C - sieve and retent; F - settling tank for coarse sediments; G - settling tank for fine sediments; H - outlet to drains. Scale: sieve diameter = 20 cm.

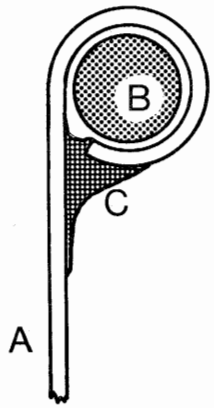

Figure 4. Sieve rim sealing. A - sieve body; B - sieve rim bracing rod; C - solder.

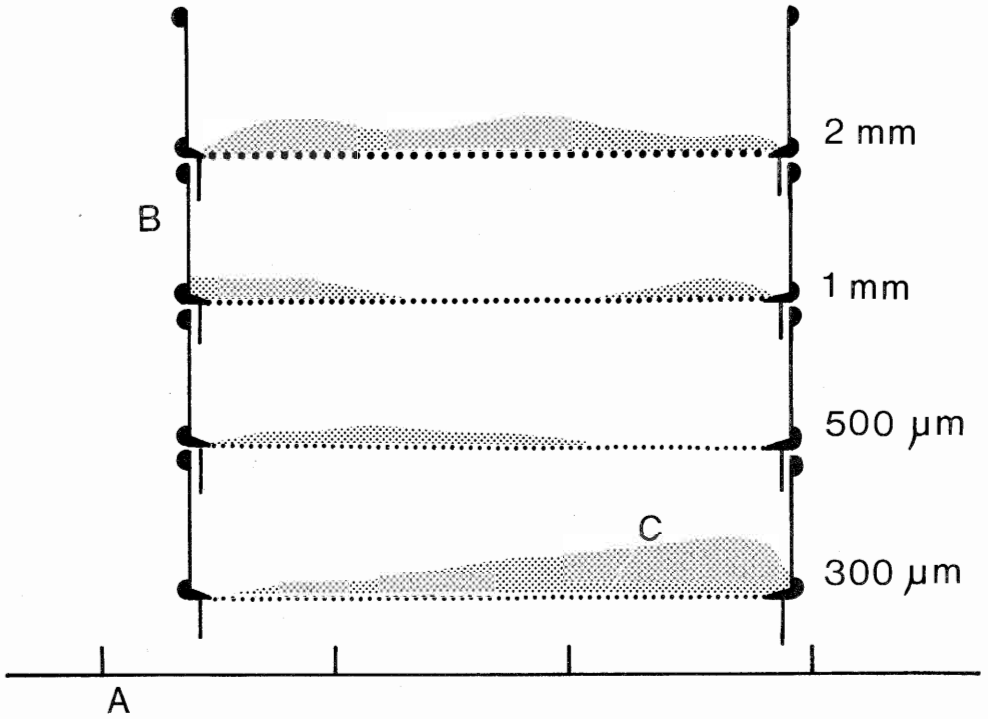

Figure 5. Bank of sieves for macrofossil extraction. A - ribbed drainer; B - sieve; C - retent.

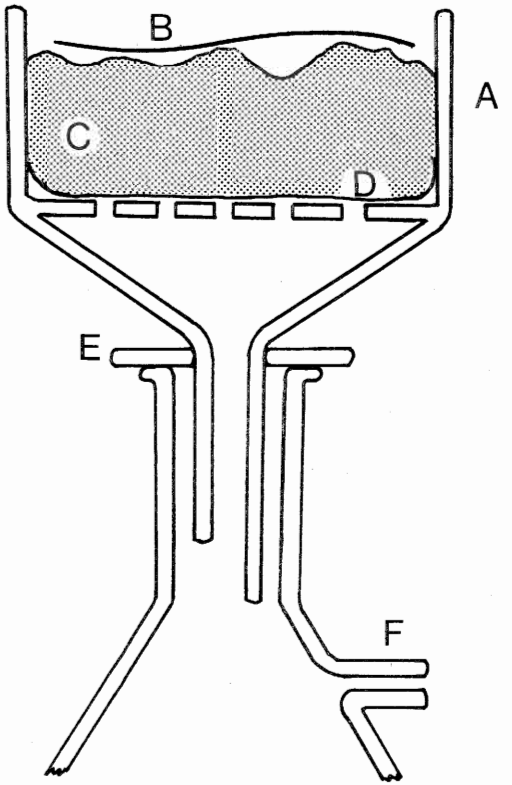

Figure 6. Simple filter for recycling paraffin. A - Buchner funnel (14 cm. diameter); B - coarse filter paper (serves only as white background for detecting particles carried over); C - glass wool; D - fine filter paper (larger than funnel diameter); E - rubber support; F - side-arm flask.

BS 2869C has been found highly satisfactory); filter for paraffin (Figure 6); industrial methylated spirits (IMS); 120 ml wide-mouthed storage jars; 3 x 1" (7.7x2.6 mm) plastic-stoppered glass vials; notebook or recording sheet; card labels; pencil.

B Contamination: All apparatus must be kept scrupulously clean; paraffin causes insect remains to adhere closely to surfaces and paraffin-alcohol-water mixtures produce a 'waxy' material in which fragments become trapped and from which they are removed with difficulty. Sieves must have the crevice around the rim filled with solder and the riveted label removed, otherwise insect remains (as well as small seeds, etc.) may become trapped, resulting in cross-contamination between samples. It is very easy accidentally to introduce enough contaminant insect remains to distort interpretation, and any contamination will obviously invalidate the records of species in space and time.

C Preparation and Recording: The condition, nature and storage history of the sample are recorded, using a sheet similar to that reproduced in Figure 2. The methods used and the response of the material to them are also recorded, and any losses or contamination (observed or suspected) carefully noted, as they will obviously affect interpretation. In the event of large spillages or contamination, the sub-sample may have to be abandoned.

The apparatus is cleaned using detergent, hot water and a scrubbing brush. A label is tied to the bucket, bearing sample and sub-sample numbers as well as site code or name, and the desired quantity of material is weighed out to the nearest gramme and placed in the bucket.

D Disaggregation and sieving: The ease with which the sample is likely to be disaggregated is tested by passing a stream of water over it (using a rubber hose and water at 40 - 50 C) and onto a 300 micron mesh sieve (Figure 7). Now, as throughout, the cleanliness of the hose must be carefully checked. The next stage will depend on how the sample has behaved.

A few sediments will fall apart readily in the stream of hot water, with gentle mechanical agitation (for example by hand, or by swirling or tilting the bucket) and need no other treatment except, perhaps, for a few small resistant lumps which may be treated more harshly. The washing time for these easily disaggregated sediments is *c.* 10 - 30 minutes.

Less friable samples may be soaked in water in the bucket for a day or so, then sieved. The bucket may be stood in a water bath at 40 - 90 degrees C, but in any case must be covered to prevent contamination and evaporation, and should not be left for more than three days without being boiled, to prevent mould growth. M. Robinson (pers. comm.) has found repeated freezing and thawing of the raw sediment to be an effective disaggregation technique especially for clays, although the effect of this method in damaging fossils has not been tested by the authors.

Most richly organic samples disaggregate more readily after being boiled in water for 15 - 30 minutes, or, exceptionally, for several hours as necessary. This is done routinely at the EAU, either before or after sieving, for boiling has the additional advantage of expelling gas from plant matter, resulting in a purer flot. The material is washed as described above (p. 8) after boiling; resistant lumps may be reboiled. Samples which do not wash down fairly easily after boiling in water may be soaked or boiled in a dilute (*c.* 10 g l-1) solution of sodium carbonate. Sample material will require some manual treatment to speed disaggregation. Such treatment must be gentle, at least in the early stages. Lumps may be pulled apart (not crushed), the bucket tipped back and forth and swirled, and the material shaken through the fingers. It is reasonable to use harsher treatment for the last five per cent or so of the material, as this may halve washing time and will only have a limited effect on the results. Automatic washing devices, using shower heads etc., have proved of little value for small samples.

Large stones, pot fragments, artifacts and bones are picked out during disaggregation; stones are returned after paraffin-flotation is complete, other remains being recorded, labelled and dispatched to the appropriate specialist.

Most fine particles (clay, silt, fine sand and fine organic debris) will be carried through the sieve by the stream of water. During washing, the sieve may be cleared of small particles trapped amongst the coarser by gently running water onto its contents and by tapping it sharply on the drainer. When sieving is completed, the retained material ('retent' - that which is retained, *OED*) is further cleaned by agitating the sieve in water, taking care not to immerse the rim. If this is not successful, the contents may be returned to the bucket and rewashed carefully. It may be necessary to empty the sieve at intervals, if the volume of retent becomes too great. A coarse sieve (typically 1 cm mesh) may be placed over the 300 m sieve to catch large fragments of wood etc. The product should be completely free of fine particles, and contain no lumps of matrix and not too much coarse debris.

E Wash-over: If there is a large quantity of inorganic matter, especially medium to coarse sand, the organic fraction may be separated from it by the 'wash-over' technique. For this, the retent is returned to the bucket and subjected to a moderate stream of cold water. When the bucket is about a third to a half full it is swirled and the supernatant, with its load of suspended organic particles, is decanted onto the sieve. The process is repeated until no further organic particles are carried off. If the quantity of organic material concentrated by this method is small, it may be sorted in its entirety. It may be desirable, however, to carry out paraffin-flotation on the inorganic fraction as a check.

F Paraffin-flotation: If the sieving process produces more than a few cubic centimetres of organic matter, paraffin-flotation is necessary to concentrate insect remains. Although this technique is reliable and effective, its success depends upon many factors. Failure to carry out the steps detailed below may lead to either too large a float or incomplete recovery. Nevertheless, with care it is possible to process large numbers of samples quickly and reliably (Jones et al., in prep.).

The thoroughly cleaned retent is drained of free water by tapping the sieve sharply a few times on the drainer and standing it at an angle of 45 degrees for up to 30 minutes (the time depending on the water-retaining properties of the material). There must, however, be no superficial drying, or very large floats will occur, since dry plant debris are wetted by paraffin, and contain air.

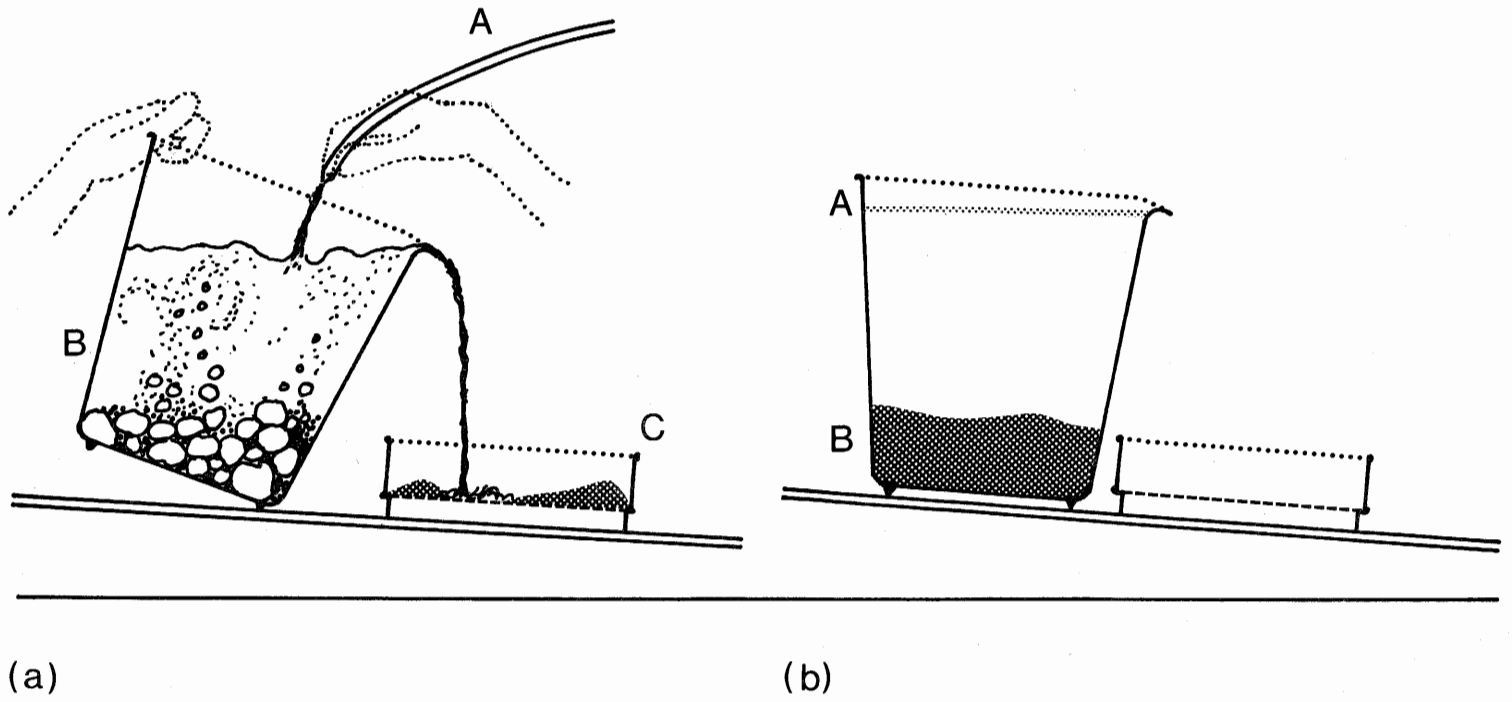

Figure 7. (a) Washing a sample. A - rubber hose delivering hot water; B - bucket containing sample; C - sieve with retent. (b) Paraffin flotation. A - flot at paraffin-water interface; B - residue.

The drained sample is tipped into a clean, lipped bucket, tapping the sieve sharply to eject as much of the sediment as possible. The sieve, with its small quantity of adherent material, is put aside (it should not be allowed to dry out, however). The material in the bucket is covered with paraffin and mixed by hand, wetting the hand first to reduce the effect of paraffin in dissolving skin oils. If the volume of the sample material is large, it may be shaken through the fingers in handfulls to ensure thorough mixing. Other methods of mixing have been found to be ineffective or to damage fossils, and it is important to avoid crushing or grinding actions. It will be apparent if the material has been insufficiently drained, as a slurry will result. Disposable surgical latex gloves may be worn when mixing by hand; a suitable brand is "Micro-touch" (Arbrook). Domestic washing-up gloves have been found to be unsuitable. Excess paraffin is poured off, taking care that no solid particles are lost, and the paraffin is filtered through glass wool (Figure 6) for re-use.

The next stage involves the addition of cold water and the separation of a flot at the paraffin-water interface, consisting of remains whose surfaces are paraffin-wetted and which float up in a bead of paraffin. The procedure is as follows:

Firstly, the traces of sediment on the hands are washed into the sieve, and thence, together with the material left in the sieve, into the bucket. Any material adhering to the walls of the bucket is washed down; this will probably be enough to produce a slurry (if not, more water should be added). The slurry is gently swirled to expel air and to increase the proportion of paraffin-wetted fossils. The opening of the rubber hose is thrust beneath the surface of the slurry (after re-checking its cleanliness with particular care) and the bucket filled by a fast flow of cold water. It is essential that during this process the lip of the bucket is directed over the sieve, in case of spillage. It is also important to avoid swirling, for this causes insect remains to adhere to the walls of the bucket, and great care must be taken to keep the end of the hose below the water surface, as the introduction of entrained air may cause excessively large floats. However, the sediment at the bottom of the bucket must be well-disturbed by the water flow. With practice, it is possible to add water quickly but in such a way that turbulence soon ceases. During filling, the hose is brought up, keeping it just beneath the water surface; the bucket is filled to about one centimetre from the lip edge and the water turned off. As the hose is removed, a small amount of sediment may be drawn into it, and thus must be expelled into the bucket by turning on the tap briefly; traces of sediment adhering to the outside of the hose must also be washed into the bucket.

The use of cold tap water has been found to be essential as floats in hot water are often very large. This seems mainly to result from the release of gas bubbles from hot tap water, but the decreased viscosity of paraffin when hot may also be responsible.

Whilst the lighter fraction of the sediment is settling it is useful, firstly, to blow gently on the paraffin surface to free debris which are floating and yet not paraffin-wetted, and, secondly, to tap the sides of the bucket sharply a number of times to release particles adhering to them. The bucket is left to stand for 5 - 30 minutes, as necessary for the residue to settle completely (Figure 7). After settling, the supernatant is carefully poured onto the clean sieve, taking care that no residue is disturbed by turbulence and so carried over. Floating particles may be encouraged towards the lip by gently blowing the surface. The bucket is refilled with water (as above) and the whole float process repeated twice. It is important to prevent flots drying on the sieve between floats; if necessary, each float may be cleaned and bottled immediately. To clean the flot of paraffin it is washed to one side of the sieve and covered with copious liquid detergent, shaking the sieve to ensure that all the material is treated. The detergent is rinsed off with very hot water (50-60 C if possible) and all traces of paraffin and detergent removed by flushing with IMS. The flot is then washed into a jar (with IMS) and internal and external labels added (in pencil, on card), ready for storage. It is extremely important that the flots are thoroughly cleaned of paraffin, since paraffin-alcohol-water mixtures produce a 'wax' (see above).

The residue in the bucket is now tipped into the sieve and drained, and the paraffin treatment repeated twice. Normally, three 'paraffinings' (P1-3), each followed by three 'floats' (f1-3) are employed. Occasionally, however, multiple f's in P1 may be advantageous, especially for some samples rich in plant debris; the latter tends to float in later P's. Where the fossil content is small, P2 and P3 may be carried out with one or two f's only. If insect material is still being recovered at P3f3, then further f's or P's may be worthwhile. P's and f's are ticked on the recording sheet (Figure 2) as they are carried out.

On rare occasions, problems will be encountered when carrying out flotation. The commonest is that excessively large flots are obtained (normal flots from 1 kg comprise only a cubic centimetre or so of solid matter). This may be due to a failure to follow the steps outlined above, but is sometimes an unavoidable consequence of the nature of the sample material. Two solutions which may be effective are, firstly, to boil the sieved sample for some hours and, secondly, to boil with strong washing soda (sodium carbonate) solution. All paraffin from the first treatment must be removed by washing with detergent before boiling. Samples of modern sediments processed for comparative purposes are particularly troublesome, since fresh plant cuticles are readily wetted by paraffin and will float; a reliable solution to this problem has yet to be found.

G Treatment of residue: If there is doubt as to the effectiveness of the process on a particular sample, the residue from paraffin flotation may be wholly or partly checked, by sorting it in water under the low power of a binocular microscope. Occasional examination of residues at random is desirable to be sure that the operator's technique has not deteriorated.

If the sample is to be examined for plant macrofossils as well as insects, the residue should be wet-sieved into fractions and sorted as described above (p.11). The material should on no account be allowed to dry out before sorting. Plant remains must be recovered from the flot as well as the paraffined residue and the two assemblages combined for quantitative work. When the residue is no longer required, it can be dried in an oven at 60 C and then sorted for bones, small artifacts etc. The stones and wood fragments picked out prior to paraffin-flotation should now be returned, and the complete residue stored dry

in a clearly labelled polythene bag. It is considered most undesirable to rely for interpretation upon assemblages of seeds recovered from the dry residues.

H Flot sorting: Flots are sorted in small amounts in alcohol in a petri dish using the low power of a binocular microscope (x12.5; minute, yet identifiable, insect remains will be overlooked at lower magnifications). Sorting requires considerable training and patience, but a discussion of sorting techniques is beyond the scope of this paper. The sorted insect remains are stored in absolute alcohol in 3 x 1" (7.7x2.6 mm) plastic-stoppered glass vials and labelled internally and externally (in pencil, on card).

Concluding remarks

If the "recipes" given here are followed, the techniques should almost invariably prove successful, producing reliable samples of biological remains from archaeological deposits in the shortest practicable time. Some deposits will prove extremely intractable, but with experience and ingenuity such problems should be overcome. However, it is desirable that beginners seek advice and training from experienced workers.

Paraffin-flotation and seed extraction should never be carried out in the open air or in dirty buildings, since the risk of contamination is immense. Even in well-designed laboratories, it is essential to take every precaution to prevent cross-contamination and the introduction of modern material into the samples. On the other hand, bulk-sieving is a process specifically designed to be employed on site.

Finally, it may be useful to give an indication of the time required to perform the various processes described here. It is impossible to provide more than a very approximate estimate; some of the figures quoted by Keeley (1978) are at variance with the authors' experience. The following figures cover a range of deposits from those most easily dealt with to the most intractable (to offer an average would, frankly, be misleading) and refer to a 1 kg sample size unless otherwise stated:

disaggregation and sieving for plant macrofossils -½ to 2 hours; sorting for plant macrofossils - 1 to 12 hours; disaggregation, sieving, and paraffin-flotation - 2 to 4 hours, plus time for soaking or boiling; sorting flot from paraffin-flotation - 1 to 12 hours; sorting dry residue from paraffin-flotation (for bones, artifacts, etc.) - 5 minutes to 1 hour; bulk sieving of five bucketsfull (50-100 l, the minimum sample thought to be representative of a large context) - 1 to 6 hours; sorting residue and flot from bulk-sieving - ½ to 20 hours.

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