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Interpretation of archaeological plant remains: The application of ethnographic models from Turkey

1

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ABSTRACT: Each step of crop husbandry and grain processing has a measurable effect on the composition of crop products and by-products. These effects have been studied in archaic agrarian systems still surviving in Turkey and are summarised in the form of 'cause-and-effect' models. Patterns of variation in the composition of remains of similar crops recovered from archaeological sites are found to closely resemble those presented in the models. The use of these models to interpret the composition of individual samples of remains of crops in terms of ancient agrarian practice is straightforward. However, when large numbers of samples are involved, a series of analytical steps is necessary. Each of these steps is explained in turn using examples from a large assemblage of crop remains from an excavation in North Wales.

Rationale

About thirty distinct operations are involved in growing a crop and converting it to food for human consumption. Recent ethnographic studies of archaic agrarian systems surviving in the present-day indicate that each of these operations has a measurable effect on the composition of each of the major crop products and by-products. The composition of these crop products thus embodies information on the way the crop was managed in the field and processed back in the settlement.

Samples of charred remains of crops from archaeological sites commonly exhibit a composition closely similar to that observed in one or other of these present-day crop products. By reference to modern equivalents, therefore, archaeological samples can provide valuable clues to the husbandry practices of prehistory (Dennell 1974; Hillman, 1973, 1981; Jones 1981). And if archaeological samples of this sort have been taken from each habitation feature, it is possible to study the horizontal distribution of the various crop processing activities represented by the different samples and, in some cases, to identify the past function of the excavated structures.

This paper attempts firstly to summarise some ethnographic models of archaic agrarian practice in present-day Turkey. It secondly outlines the analytical steps by which the major classes of crop product (as identified from the ethnographic models) can be recognized in complex assemblages of charred remains from archaeological sites. The paper thus explores one of the methods by which the modern model can be used to identify evidence of specific agrarian practices in archaeological remains.

Alternative (non-ethnographic) methods of interpretation

It must briefly be stressed that, in working from explicitly defined ethnographic models, the interpretive method outlined here and in the parallel paper by Glynis Jones is fundamentally different from that explored by Robin Dennell (1972, 1974, 1976). In Dennell's approach, variations in the composition of plant remains were interpreted principally by reference to assumed past functions of the site contexts with which the remains were associated, and, in certain cases, by comparison with grain size distribu-

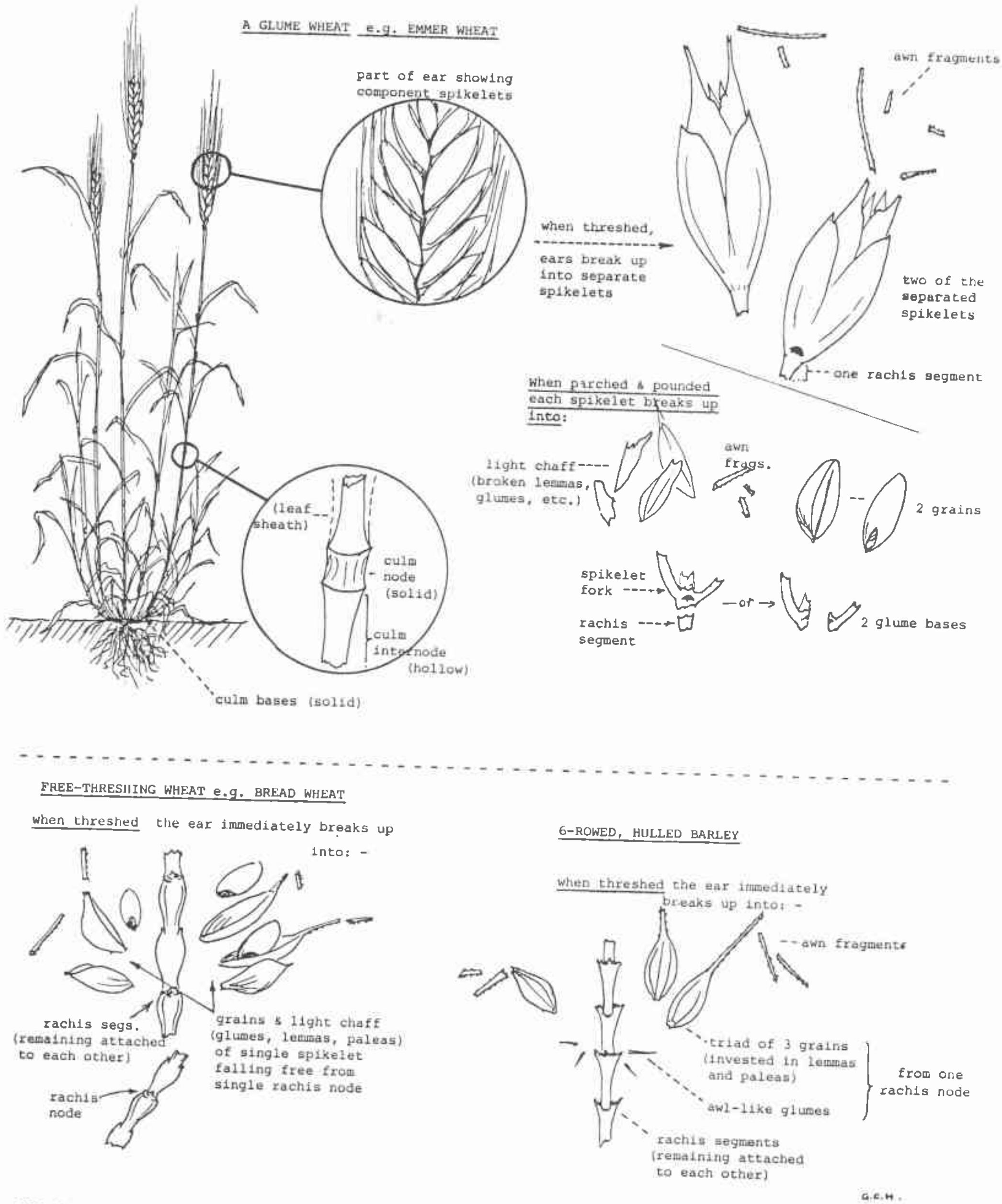


FIG. 1. Some of the major components of cereal ears - as an explanation of English terminology used in the flow diagrams and text. (Reproduced from Hillman 1981).

tions generated in laboratory sieving experiments. Thus, in working directly from the ancient remains themselves, Dennell approached interpretation from precisely the opposite direction to the ethnographic approach outlined below and in the following paper by Glynis Jones. It should similarly be stressed, therefore, that his subsequent reconstructions of archaic grain-processing sequences (eg.in Dennell 1976) owed much to speculation (as he himself has stressed) and relatively little to ethnographic observation.

1 ETHNOGRAPHIC MODELS FROM TURKEY

Only a brief outline of the available models from Turkey will be offered here, as they have already been published elsewhere (in Hillman, 1981 and forthcoming a.)

1.1 Field methods

The first step in assembling the ethnographic models was to locate villages in remote, generally mountainous areas of Turkey where archaic forms of indigenous crops were still grown by peoples whose agrarian technology owed nothing to the 20th century and appeared, indeed, to have remained unchanged from technologies available in the same areas three or more thousand years ago. My studies of archaic agriculture began, in fact, in the village of Aşvan in Eastern Anatolia in 1969 as part of the 'Aşvan Project' of the British Institute of Archaeology at Ankara (see French et al., 1973).

Having established contact with the always very hospitable villages, the first step was to list the crops grown and to collect information on the full range of systems of crop management applied in the area. For each of the crops under cultivation the procedure was then as follows:

a) Detailed records were made of the full sequence of husbandry and processing methods applied to each of the crops grown. Details of the tool types used were also recorded.

b) Samples of ca. 2 kg. were taken from every crop product and by-product in every processing sequence - from threshing onwards. However, sampling was never straightforward: samples had to be collected as and when the relevant operations were being undertaken in the various households of the village or on the various threshing yards around the village. In villages where only brief visits were possible, sampling was inevitably very 'piecemeal'.

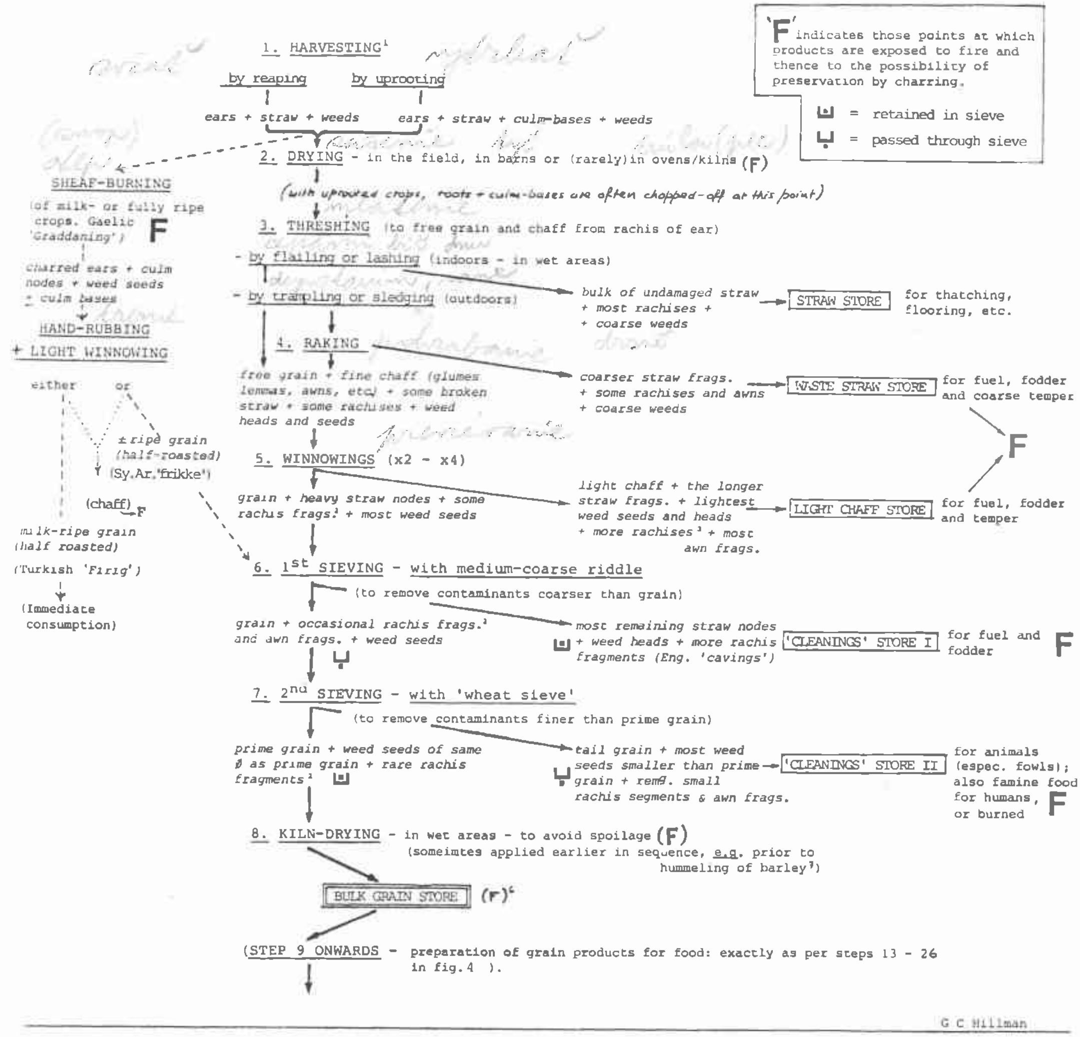
c) Together with each sample, it was necessary to record details of (i) how that particular crop had been managed in the field (eg. frequency of irrigation, whether weeded, cutting height, etc.), (ii) what processes it had been through prior to the point at which the sample was collected, (iii) the classes of village context in which each processing stage occurred and in which the crop product (or by-product) was stored, fed to animals, burned, or tossed straight onto a midden.

d) The samples were next sorted and the components identified. This allowed the composition of each product to then be classified (i) in terms of the relative abundance of each species of weed seed and class of chaff/straw residue, (ii) in terms of any major differences in the frequency distributions of grain and weed seed sizes.

e) Data from samples representing the equivalent products of the same crop were then compared, as were data from samples representing different stages of processing and different systems of husbandry in the field. In this way it was possible to identify the most obvious of the effects of each of the different operations (or systems of field management) on the composition of the major crop products and by-products.

1.2 The results

In the course of this work, it quickly became clear that the major operations had clearly discernible and consistent effects on the composition of crop products. These effects are summarised - albeit only in qualitative terms - in figs. 2 & 4 (free-threshing cereals) and 3 & 4 (glume wheats). (Fig. 4 outlines the later stages of grain processing which are the same for both glume wheats and free-threshing cereals. Fig. 4 therefore represents the continuation of both figs. 2 and 3). In these flow diagrams, the numbered steps in the left-hand column represent the principal stages of crop processing. Entries in the right-hand column list the principal components of the major

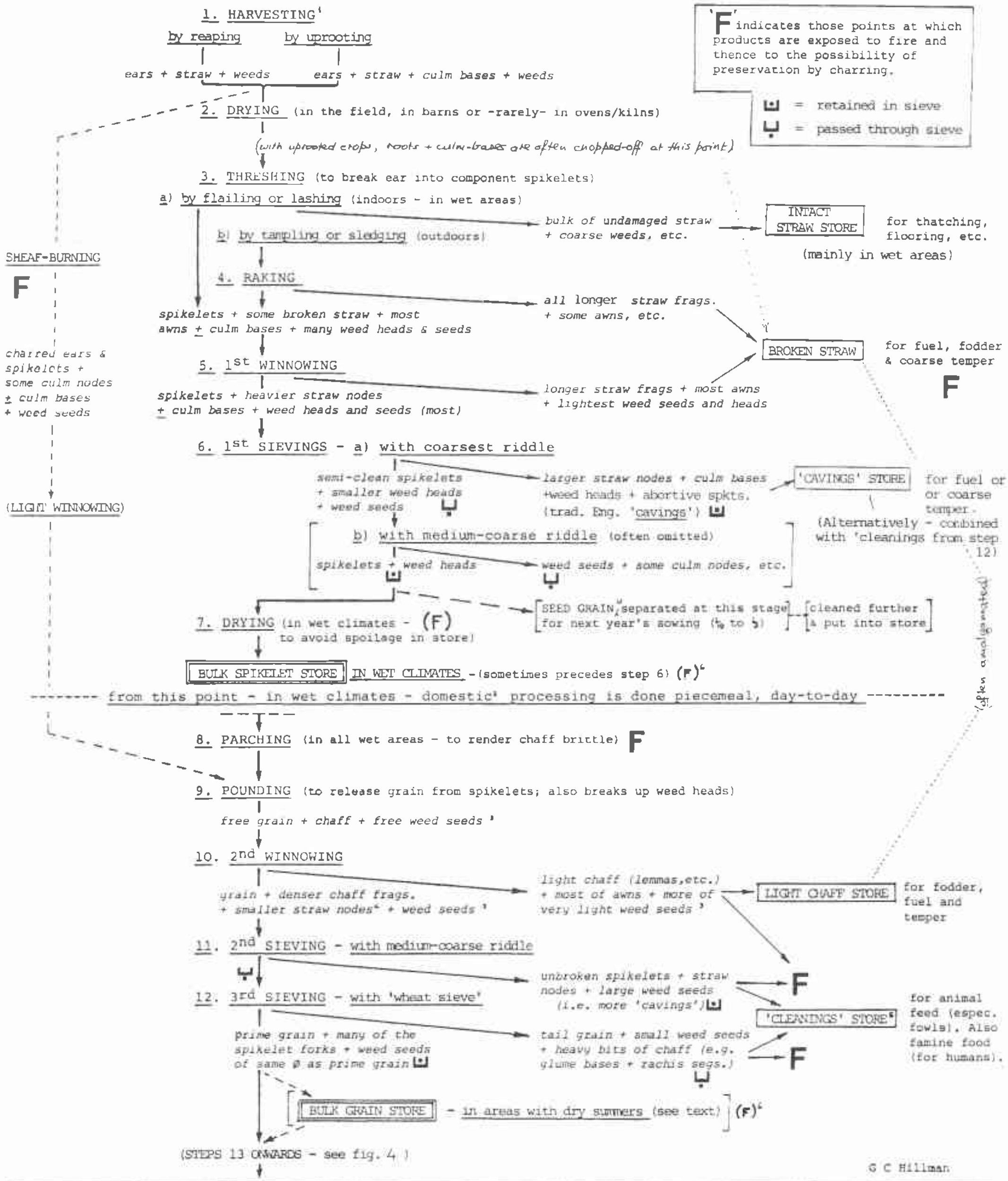


1. To limit the complexity of the diagram, separate harvesting of ears and straw and its effects on composition have not been incorporated, though they are discussed in the text. 2. The heavy, basal rachis segments are disproportionately well represented in the primary products (relative to the lighter, upper segments). 3. Many of the lighter, upper segments of broken rachises are winnowed out with the fine chaff. 4. These two sets of cleanings are often amalgamated (see text).
5. Fenton 1978; Grant 1961 . 6. If prime products are stored in pits, then annual cleansing of these pits by firing will char any grain adhering to the sides (see Reynolds in this volume). 7. The sequence for barley (and oats) differs slightly - in the hulled forms - in that an extra step (HUMMELING) is often applied to remove the remaining, basal part of their awns. This is generally done prior to step 5.

Fig.2. THE TRADITIONAL PROCESSING OF FREE-THRESHING CEREALS e.g. BREAD-WHEAT, RYE (AND BARLEY[7]) and the composition of their products when harvested together with the straw[1]

The sequence of operations applied to pulse crops - e.g. horse-beans, field-peas or vetches - is identical in most respects, though the sieve mesh sizes are different and the terminology for chaff fractions is not strictly comparable).

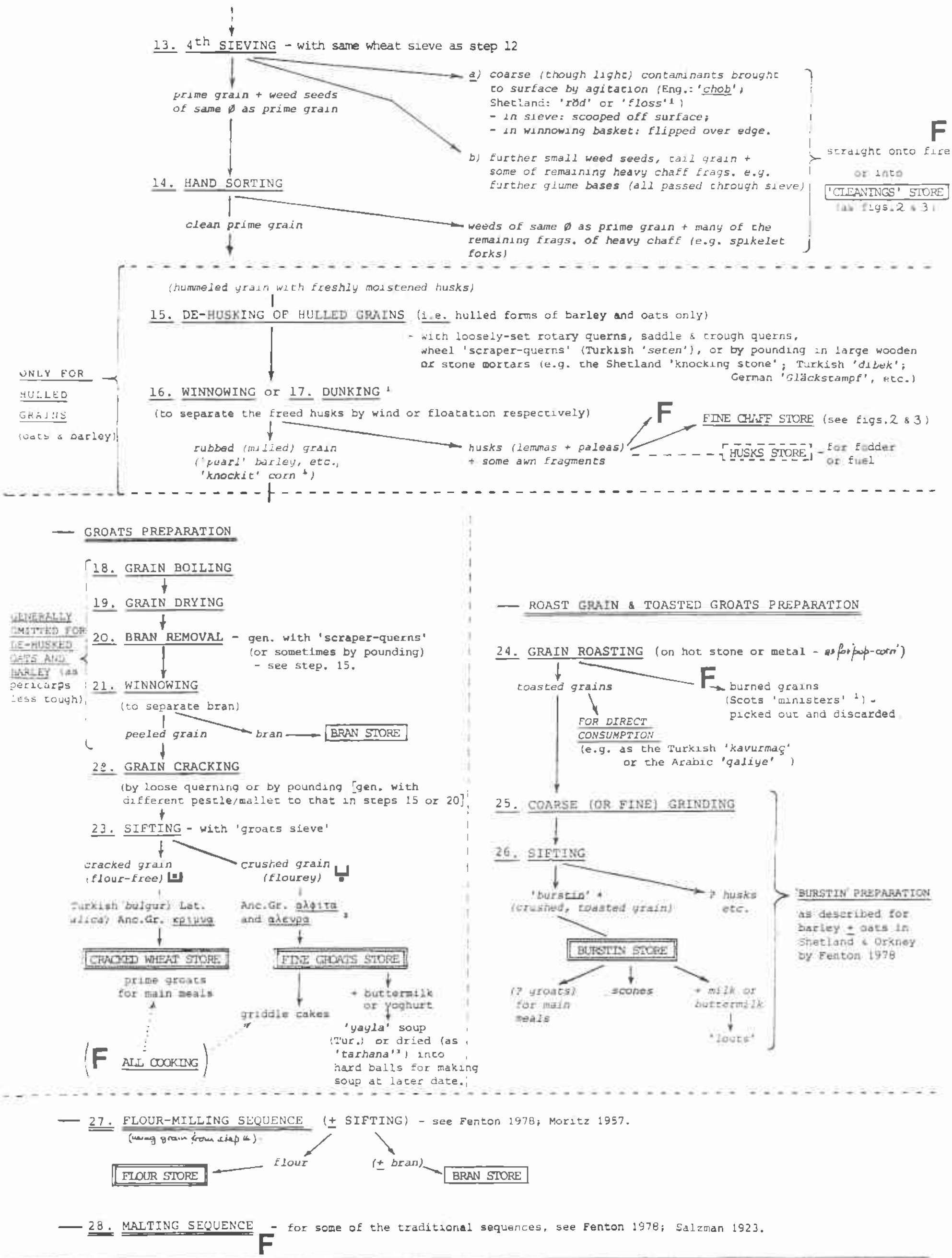
(reproduced from Hillman 1981)



1. To limit the complexity of this diagram, separate harvesting of ears and straw and its effects on composition have not been incorporated, though they are discussed in the text. 2. Domestic as opposed to manorial. 3. Most of the weed seeds at this stage derive from immature weed heads broken up during pounding (step 9). Many of these seeds are therefore immature to varying degrees. 4. Especially conspicuous are the basal rachis segements left at the top of the straw. 5. The 'cleanings' from steps 11 and 12 are often stored separately (see text), in which case it is the 'cleanings' from step 12 alone that serve as famine food. In wet areas, however, these cleanings are generally thrown straight onto the fire (during the winter months, at least) as they are separated in small quantities day-to-day. 6. (See footnote 6 of fig. 2).

Fig. 3. THE TRADITIONAL PROCESSING OF GLUME WHEATS e.g. EMMER, SPELT AND EINKORN and the composition of their products when harvested together with the straw[1]

(from Hillman 1981)



1. From Fenton, 1978. 2. See Moritz, 1957. 3. Anatolian Turkish. Interestingly, the equivalent term in NW Iranian Kurdish (an Indo-European language) is 'groot' ; could this be cognate with English 'groats' ? If so, it would seem to suggest that this quick and very palatable way of consuming grain products is of some antiquity. 4. Once again, equivalent products can be found in most of traditional agricultural societies that still survive; e.g. the Arabic 'gerishé' which is eaten precisely as the Shetland 'louts' .

Fig.4. FINAL STAGES OF GRAIN PROCESSING - (CONTINUED FROM FIGS. 2 & 3).

These final stages are essentially the same for both glume wheats and free-threshing cereals, though they differ in hulled grains (hulled barleys and oats) as against naked grains (wheat, rye and the naked forms of barley and oats)

(from Hillman 1981)

by-products. The entries inserted between the numbered processing stages (left hand column) list the principal components of the prime products. Most of these prime products are transitory: they are quickly fed into the next stage of processing. As a result, the majority of them are unlikely to be preserved on archaeological sites and are of only limited archaeological relevance. Items in boxes are storage products.

It should perhaps be added that these models - one for glume wheats (figs.3 & 4); one for free-threshing cereals and pulses (figs. 2 & 4) - were distilled from a collection of different flow diagrams, each of which summarised separately the pattern of changes in product composition which occurred -

a) in different geographic areas (principally 2 types: wet- and dry-summer areas);

b) with different methods of harvesting - uprooting
- reaping ears only
- reaping ears and straw together - etc.

(each of these harvesting methods can result in certain extra components such as culm bases being present or absent in certain products);

c) when sheaf burning was used to eliminate all the early processing stages.

Figures 2, 3 and 4 therefore represent an attempt to summarise all these different sequences in just 2 flow diagrams. It is for this reason that they appear somewhat cluttered. (The originals from which they were summarised are inevitably less complex).

1.3 Repeatability

For any one crop and any one processing sequence type, there was remarkable consistency in the composition of the products and by-products produced at any one stage of processing. This was true not only when comparing products from different households in the same village, but also when comparing products from different villages. This apparent consistency is now made even more convincing through Glynis Jones' ethnographic studies in the Aegean (Glynis Jones, 1981 and this vol.): her results reveal closely similar patterns of variation in product composition and indicate just the same patterns of cause and effect. It must nevertheless be stressed that there is some flexibility in the points in the processing sequence at which certain operations (e.g. extra rounds of sieving) are carried out. These differences seem to be related principally to the stage at which the grain or spikelets are put into bulk storage (see below).

1.4 LIMITS OF GEOGRAPHICAL RELEVANCE OF MODELS

There are, alas, no ethnographic studies of primitive agriculture in N or W Europe which have analysed the relationship between observed agrarian activities on the one hand and composition of products on the other. Is it feasible, therefore, to use these ethnographic models from Turkey and Greece to interpret crop remains from central or northern European sites in terms of past agrarian practice?

a) Crop-type differences between modern Turkey and ancient Europe?

Almost all the major cereals and pulse crops grown in Europe in the recent or distant past are still to be found under cultivation in the Near East, especially in eastern Turkey. For the purpose of the ethnographic studies outlined here, particular attention was given to the cultivation and processing of Emmer (T.dicoccum) because it was the glume wheat that dominated much of Europe and S.W. Asia for several millennia. However, free-threshing cereals and pulses were more widely cultivated than Emmer; there was, for example, no Emmer in the Aşvan area. The results for free-threshing crops are consequently more complete than they are for Emmer for which the results must still be regarded as somewhat provisional, despite the passage of 10 years since their collection. (Further work on Turkish Emmer cultivators is now in hand).

b) Weed flora differences between Turkey and Europe?

A more obvious objection is that the weed floras of Turkey are different from (and certainly richer in species than) those of northern Europe. In the models outlined here and by Glynis Jones (this vol.), this problem has been pre-empted: as indicated in Hillman (1981 - figs. 5, 6 & 7) the different crop products and by-products are not distinguished on the basis of particular weed species being present or absent, but purely on the sizes and densities of the weed seeds present and the height of the weeds when growing in the field. The actual species represented in each size or height class is largely irrelevant, therefore.

c) Differences in agrarian technology

Despite their never having recorded the composition of crop products, ethnoagricultural studies in Europe do offer a wealth of information on traditional agrarian practices and tool assemblages in recent times. (Examples include Maurizio (1927), Leser (1931), and a wealth of articles in journals such as Tools and Tillage, Agartorteneti Szemle (Hungary), and Bealoideas: Journal of Folklore of Ireland Society). From these and other accounts, it is clear that the techniques applied in recent times in central and northern Europe to the cultivation and processing of any one crop species differed remarkably little in principle from the techniques used today in parts of Turkey. The reason for this uniformity is simple enough: in the absence of modern technology there are very few ways of doing any one of the jobs involved in growing and processing any particular crop. For example, to de-husk grains of hulled barley, most of the recorded groups from the Shetlands to the Khyber Pass seem to use some form of pestil and mortar. (For the Shetlands example, see Fenton, 1978). Admittedly, occasional Anatolian households use either a widely-set rotary quern or even a heavy 'seten' for the same job, but this practice seems uncommon. Effective alternatives are clearly rare.

Striking differences do, nevertheless exist in threshing methods, in the implements used for winnowing, and in the size and shape of pestils and mortars used for dehusking grain or breaking-up spikelets. (Details are given in Hillman, forthcoming a). Threshing, for example, is effected by using anything from small beaters and flails to threshing sledges and trampling of hooves. These differences appear to be broadly correlated with the wetness of summer: in dry areas, all the dusty jobs such as threshing, winnowing and pounding can be done on a large scale (often communally) out-of-doors; in a wet area they cannot, though cultural intrusion can clearly create anomolies here. For the purpose of gathering information for these models, a conspicuous advantage of working in Turkey was that one of its major areas of Emmer cultivation in which agrarian technology retains its archaic form also has wet summers. This area embraces the eastern end of the Pontus Mountains overlooking the Black Sea where annual rainfall exceeds 750mm. Within Turkey, therefore, it was possble to study both wet- and dry-summer adaptations of traditional crop husbandry.

However, the different processing methods of wet and dry areas have only minimal effects on the composition of products. This last fact is both an advantage and disadvantage: it allows the one model to be used in both wet and dry areas, but it generally precludes the possibility of differences in composition being used to identify whether it was the dry-type or the wet-type system that was used.

The one major difference in processing sequences that seems to distinguish areas with wet and dry summers (within Turkey, at least) is the point in the sequence at which the grain of glume wheats is put into bulk storage: in dry areas, the Emmer is threshed, winnowed, pounded (i.e. dehusked), re-winnowed, and the freed grain partially cleaned - all in bulk, out-of-doors during the summer. It is therefore the partially cleaned **grain** which is put into bulk storage. In areas with wet summers, however, the crop is processed in bulk only up to the stage of spikelet cleaning, and it is the **spikelets** which are put into storage (see fig.3). Indeed, in some households most of the crop is bulk-stored as sheaves as, for example, in parts of Scandinavia. All the remaining steps of processing are then completed on a small scale, day-by-day, as and when grain is needed to prepare food for immediate consumption.

Despite these differences, the overall sequences of operations applied in both wet and dry areas is basically the same, and the compositon of the crop products in either area also appear to be no different. The principal contrast between grain processing in wet and dry areas is therefore to be found in the contents of grain stores and in the tools, which are sometimes of quite different type (as in the case of threshing equipment) or much smaller in size (as in the case of the pestils and mortars used for pounding and dehusking).

Thus, whenever charred remains of grain stores are recovered, it is immediately possible to identify which of the grain storage patterns was in use, and this, in turn could perhaps suggest which of, say, the threshing tool traditions might have been represented. Far from limiting the application of the model, therefore, these differences in storage practice improve its resolution. (Archaeological examples abound for bulk storage of both grain and spikelets and will not be listed here).

However, it must be stressed that the pattern of storage practices of wet- and dry-summer areas is distorted by at least two factors:

(i) The first factor is **cultural intrusion.** It seems probable that at least some farmers migrating from wet areas into dry areas temporarily retained their former, indoor-adapted processing practices characterised by the bulk-storage of spikelets. Examination of the grain stores of sites representing southerly penetrations of, say, early Indo-Europeans into the Mediterranean zone might therefore allow a crude measure of either conservatism or flexibility in prehistoric agrarian technology.

(ii) There is a second factor. The development of large farm buildings such as barns would have allowed bulk-processing of crops to be undertaken indoors. In even the wettest areas of oceanic Europe, therefore, the rise of manorial farming under Roman rule presumably allowed glume wheats from the manorial lands to be bulk-processed indoors, right up to the stage of grain-dehusking and cleaning, ready for bulk storage and trade.

Nevertheless, it seems unlikely that this novel system of bulk-processing would have been easily imposed on native farmers lacking large buildings. The agrarian technology of native farmsteads and Roman manors may, therefore, have differed dramatically, especially in the processing of glume wheats. This hypothesis will, however, remain untestable until excavators start showing more interest in recovering crop remains from native farmsteads of the Roman period. Hitherto, most have preferred to unearth yet more garrisons and manors and let the life style of the population's majority remain a matter for conjecture.

1.5 LIMITS OF TEMPORAL RELEVANCE OF MODELS

Ethnographic evidence presented in this volume by David Harris suggests that several of the operations involved in harvesting and processing grain crops are not unique to agrarian societies: they were (and in some cases, still are) an integral part of the technology of non-agrarian societies in areas where borrowings from intrusive agrarian groups appear improbable. It therefore seems reasonable to suppose that such techniques were incorporated into agrarian practice from its inception.

In principle, therefore, it seems that certain components of our models can contribute to the interpretation of plant remains from even the earliest agrarian sites. Whether the same could be claimed for the complete crop processing sequences is open to question: so far, I have personally felt reluctant to advocate the use of our models on sites earlier than the late ceramic Neolithic. Such reservations may be unfounded: not only are there few efficient ways of effecting any one stage of processsng, but there are few possibilities of altering the **sequence** of these operations: for example, you cannot sieve before you winnow, because the light chaff and straw would immediately clog the sieves.

Arguments for continuity of agrarian technology during the past few millennia are further supported by the ever increasing number of samples of plant remains whose composition has proved to be remarkably similar to that of present-day products of the same crops. A recent example comes from 3rd century AD Wilderspool in England (Hillman, in press). Here, a huge cache of charred chaff of glume wheats (mainly spelt) exhibited ratios between the major components which were precisely the same as those found today in the 'waste fraction from the fine-sieving of dehusked grain of glume wheats indicated in stage 12 of the flow diagram - fig. 3. (The major components included spikelet forks and glume bases, rachis internodes, tail grains, prime grain, small weed seeds, and awn fragments). Composition of this type is entirely different from that of any other crop product or by-product found in the present-day, and the implication must be that the spelt crop at Wilderspool was harvested and processed by methods closely similar to those outlined in

TABLE 1. COMPOSITION OF THOSE CROP PRODUCTS LIKELY TO SURVIVE IN CHARRED REMAINS FROM ARCHAEOLOGICAL SITES – GLUME WHEATS ONLY

▬ = very rare
X = few
XX = some
XXX = lots
Items in brackets '[ ]' = present only if crop was harvested by uprooting.
Small encircled crosses '(XXX)' = items released only as a result of fragmentation of other items (such as whole spikelets) after the latter have been charred.
The symbol '≡' = 'the equivalent (of)'.
Σ = 'sum of ...'.

Characteristic components: a to q.

product number (used only in this table)	the crop processing stages which generate each class of product (numbered as in figures 3 and 4)	crop product classification code (as used at Cefn Graeanog)		a culm bases	b culm nodes	c awn segments	d intact spikelets (non-basal)	e intact spikelets (basal, abortive)	f spikelet forks	g glume bases	h non-basal glume fragments[1]	i rachis internode segments	j grain - prime	k grain - tail	l weed heads - much larger than spikelets	m - ± same size as spikelets	n - smaller than spikelets	o seeds larger than prime grain though smaller than spikelets	p seeds of same size as prime grain	q seeds smaller than prime grain	commonest amalgamations (pre- and post-burning)
1.	not numbered	BΣ (≡ of all B classes combined).	Residues from burning of whole sheaves (either from accidental burning of sheaf-stores or delib. sheaf-burning as in side-loop of figure 3)	[XX]	XX	XX	XXX	XX	XXX	XXX	XXX	XXX	XXX	X	XX	XX	X	X	XX	XXX	
2.	4, 5, 6a	B1	'Straw waste' from raking, 1° winnowing, and coarse riddling (ie. threshing floor waste)	[XX]	XX	XX	▬	XX							XX			X	XX	XXX	
3.	8	≡ of B2 + B3 + B4 + B5 combined.	Threshed spikelets charred during parching and, in wet areas, accidental burning of spikelet stores	[X]	X	X	XXX		XXX	XXX	XXX	XXX	XXX	X		XX	X	X	XX	XXX[3]	
4.	11 (+ 6b)	B2	Coarse sievings (larger than prime grain)	[X]	X		X	XX									X	▬			
5.	12 (+ 13b)	B3	Fine sievings (smaller than prime grain)	[▬][5]	▬[5]				XX	XXX		XXX		XX						XXX	
6.	follows 13	B4	Semi-clean grain in bulk storage charred as a result of accidents in grain stores or in course of sterilization of storage pits	[▬][6]	▬[6]	▬			X	X		▬	XXX	X					XXX	X	
7.	14	B5	Cleanings from hand-sorting (applied immediately prior to the grain being prepared as food)	[▬][6]	▬[6]	▬			X	X		(▬)							XXX[4]	X[4]	
8.	24	B6	Clean prime grain (charred during roasting, etc.)										XXX	X							

1: Non-basal glume fragments generally survive only if charred while still part of intact spikelets which were subsequently fragmented. 2: These arrows indicate the fragmentation of items which have already been charred - producing a range of smaller items. 3: These loose weed seeds are present in this fraction only if the sieving applied at step 6b (fig. 3) is omitted. 4: These arrows show the derivation of some of the weed seeds from the fragmentation (during pounding in step 9 of fig. 3) of immature weed heads or capsules. Such seeds often exhibit clear signs of immaturity. If step 6b is applied rigorously, almost all the weed seeds present in these products will be of this type. 5: These items derive primarily from 'chob' scooped off the surface of the agitated grain in step 13. This chob is commonly amalgamated with the 'fine cleanings' (B3). 6: In this fraction, the only culm nodes and lumps of culm-base present are those which are the same size as the grains. Note: BΣ = sum of B1 + B2 + B3 + B4. B4 = sum of B5 + B6.

the glume wheat model in fig.3.

Remains of agrarian tools from sites such as Neolithic Egolzwil in Switzerland tell a similar story (see Wyss, 1969, 1971). Here the beautifully preserved array of implements include most of those needed to effect the major steps of processing as practised today and outlind in figs.3 and 4. Even a grain sieve appears to be represented (see photograph of item - catalogue No.44416 - described as a 'Tasche' in Wyss 1971). The one tool which seems to be missing is a winnowing fork or shovel: perhaps they used baskets or fans instead, though it should be noted that sieves, too, can serve as 'baskets' for small scale winnowing (Hillman, forthcoming a). Such a suite of perfectly preserved processing tools are, of course, unique in the European Neolithic. However, their rarity in remains recovered from Neolithic wetland sites where wood can theoretically be preserved by waterlogging is clearly not evidence that such tools were rarely used at that time. After all, wooden tilling implements are equally rare, and yet they, too, must have been in general use.

An interesting exception to temporal continuity in grain storage systems is provided by the charred grain from Assiros Toumba and Iolkos reported by Glynis Jones (1981, 1982 and forthcoming). Her work reveals that the glume wheats at these two Greek sites (where the summers were presumably dry) were bulk-stored as spikelets. This is the pattern that today is more typical of areas with wet summers. At these sites, therefore, we must conclude either (i) that storage practices were of a tradition intrusive from areas with wetter summers, or (ii) that this particular feature of crop processing practice has changed during the past few millennia. Neither possibility would be suprising.

2. REDUCING THE COMPLEXITY OF THE MODELS

2.1 Deletion of superfluous variables

Superficially, the models summarised in figs. 2, 3 and 4 may seem somewhat complex. However, on most of those archaeological sites where plant material is preserved merely as a result of having been charred, only a very few of the crop products and by-products are represented. For the purpose of interpreting the plant remains from the average site, therefore, much of the detail can be eliminated. This simplification involves two steps:

a) Remove all of those products that are unlikely ever to be exposed to fire and thereby preserved by charring. In figures 2, 3 and 4, the points in the processing sequences at which the products are exposed to fire are indicated by 'F'. We can therefore eliminate all products **not** marked with an 'F', including all the transitory prime products which exist for only a short period before being fed into the next processing stage.

b) Within the products that remain, we need consider only those components which, when exposed to fire, are small enough and dense enough to drop into the ashes and be charred rather than being burned to ash themselves. On this basis, we can eliminate all straw internodes, most of the lighter straw nodes, leaf fragments, all the light chaff (i.e lemmas, paleas, glume tops, the lighter rachis segments and most of the awns) together with most of the lighter weed seeds. The sort of weed seeds eliminated in the course of burning are those from genera such as **Filago, Salix, Calamagrostis** and **Imperata** which, because of their attachment to a feathery pappus (**Filago**) or to florets with rachilla hairs (**Imperata**), are unlikely to be able to drop into the ashes but instead remain high in the fire and get burnt away. However such seeds rarely get onto a fire anyhow. (Note: Among the chaff fractions which commonly survive [generally as components of coarse or fine cleanings] are dense segments of oat awn and the dense basal parts of the rachises of barley and naked wheats).

The two sets of eliminations (a and b above) now leave us with a maximum of eight products which we are likely to encounter on archaeological sites. The eliminations have also greatly reduced the range of components in each product. This reduced range of products and their characteristic components are tabulated in table 1. Of the eight products listed, the first two (sheaves and straw waste respectively) are rarely represented on the average site. The same is true of 'cleanings from hand-sorting' (the 6th product listed in table 1). The range of charred products likely to be encountered on most sites is therefore very restricted.

2.2 Problem of fragmentation of charred remains

Table 1 is complicated by the fact that certain items such as charred spikelets and weed-heads break into fragments, and in doing so they generate new components. Spikelets, for example, can break up to give six different classes of component. (In table 1 these 'secondary components' are represented by smaller crosses - 'xxx'). But even in mixed samples, recognition of these 'secondary components' is generally no problem: firstly, barring the effects of differential preservation, ratios between the numbers of each of the more durable classes of component produced by the fragmentation of spikelets are closely similar to the equivalent ratios in intact spikelets and readily recognised as such. Secondly, seeds and other components liberated by the fragmentation of weed heads (capitulae of Dipsacaceae and Compositae, capsules of Papaveraceae, Caryophyllaceae and Primulaceae, etc.) are often recognizable from their state of immaturity (see footnote 4 of table 1).

Barring these minor complications, it is hopefully clear from table 1 that
a) there are relatively few crop products that are likely to be found on archeological sites in charred form,
b) the principal components of each product are sufficiently different (both in type and in their relative abundance) for charred remains of the different products to be readily distinguished.

3. THE PRODUCTS OF TABLE 1 MOST COMMONLY ENCOUNTERED ON ARCHAEOLOGICAL SITES

On most of the small 'primary-producer' (e.g. farmstead) sites in Britain that have been examined so far, the products most commonly preserved by charring are the 'fine sievings' from stages 12 and 13. These may or may not include a minor admixture of some coarse sievings from stage 11. As indicated in fig. 3, these two by-products are today quite often amalgamated in a common 'cleanings' store, though the decision to amalgamate depends on the eventual uses anticipated for either by-product; e.g. if the 'fine cleanings' with their tail grains and weed seeds are likely to be needed as famine food, then coarser 'cleanings' would not be added. If, on the other hand, the cleanings are for feeding fowl or for burning, the two by-products will often be amalgamated. In addition to these cleanings, recent excavations at small primary-producer sites have also produced occasional caches of prime grain.

However, it is on larger sites - whether 'manorial' farming sites or 'consumer' sites - that it is more common to find charred remains of prime products in quantity, whether in the form of grain or spikelets. In many cases, entire grain or spikelet stores have been charred in the course of wholesale destruction of the entire site. Examples are too numerous to quote.

In other cases, charring of prime products (grain or spikelets) seems to have occurred as a result of accidents during large-scale parching of spikelets prior to pounding or drying of malt (germinated grain or spikelets) intended for alcoholic fermentation. A recent example of malted products came from the Roman manorial site of Catsgore in Somerset (England). Here 4 out of 5 large 'drying kilns' produced remains of spelt which appeared to represent deliberately sprouted (i.e. malted) spikelets that had been accidentally overheated in the course of drying (Hillman, 1982a). Samples of charred remains that may again represent malted products have also been reported from the post-Roman site of Poundbury in England by Monk (1983). Again, it seems to be the larger sites with non-domestic modes of production where such accidents occurred most often. Samples similar to those from Catsgore and Poundbury have doubtless been published from a number of sites in continental Europe of which I am at present ignorant. This paper does not classify or discuss malted products separately from bulk-stored spikelets and grain, as the difference lies merely in the grains being deliberately (and therefore relatively evenly and extensively) germinated. In any case, criteria for distinguishing between malt and other grain products are discussed in some detail elsewhere (in Hillman, 1982 a).

3.1 Waterlogged sites

In stark contrast to everything so far suggested in this section, there is one class of site on which models for interpreting plant remains in terms of agrarian practice cannot be simplified as described under 2.1 above. These are habitation sites such as Feddersen Wierde where plant remains are preserved in bulk as a result of large-scale waterlogging of habitation deposits. The daunting task that the analysis of such assemblages represents is best appreciated from reading the remarkable account of the plant remains from Feddersen Wierde presented by Prof.Körber-Grohne (1967). On such sites, any and every one of the products and by-products listed in figs. 2, 3 and 4 can theoretically be preserved in quantity by waterlogging. On sites of this type, therefore, the narrow range of products summarised in table 1 is entirely inadequate, and the models summarised in figs. 2, 3 and 4 must regrettably be used as they stand.

Waterlogged people

The gut contents of Tollund man and Grauballe man studied by Helbaek (1950, 1951, 1958) are a class of non-charred plant remains worthy of a supplementary note of their own.

The use of 'fine cleanings' as famine food was mentioned above (in sect.3). (The 'fine cleanings' referred to here are those from stages 12 and 13 of figs. 3 and 4). In the author's view, the compositon of the contents of both sets of guts (Tollund & Grauballe) accord closely with the composition of 'fine cleanings' enriched with a little extra prime grain. As a typical formula for famine food, such fare would, perhaps, not have been deemed inappropriate for condemned prisoners - if that is what the two men were. Arguments for this interpretation are offered in Hillman 1981, 156-8.

4. PROBLEMS OF ON-SITE MIXING OF CROP PRODUCTS

The limitations that on-site mixing of crop products could impose on the interpretation of plant remains was first discussed in detail by Richard Hubbard (1976a, 1976b). Certainly, mixing of crop remains can be expected to have occurred when, for example, the charred residues from various minor accidents during spikelet-parching or grain-roasting were dumped on the same midden as the ashes from the burned fuel of hearths and ovens. It could be argued, therefore, that the only unmixed samples will come from those 'primary' contexts where the products were initially charred. If this is true, then, all that can be retrieved is information on the last event in each context prior to its final abandonment.

In practice, however, it seems that mixing of products from different operations was not always so widespread. Indeed, it is feasible to use samples recovered from even 'secondary' contexts such as middens so long as the composition of the remains suggests derivation from a single class of operation. At third-century AD Wilderspool, for example, the composition of charred spelt remains from a very large midden deposit matched precisely the composition characteristic of the waste fraction from step 12 of the processing of present-day glume-wheats (see figure 3) together with a few straw nodes representing, perhaps, the waste from step 11. Furthermore, the composition was precisely the same in all samples taken from different parts of the extensive deposits concerned (Hillman, 1983 b).

Purity and uniformity of this sort would not, perhaps, have surprised us as it did if we had considered exactly which crop products were likely to have been regularly exposed to fire in the day-to-day life of a Romano-British farmstead in a wet climate. Indeed inspection of the ethnographic models summarised in figs. 2, 3 and 4 and the charred products classification in table 1 suggests that the only products which, on any one day, are likely to leave charred remains in habitation deposits are precisely these same cleanings from stage 12 (+ 13) and, in much smaller quantities, the cleanings from stage 11.

In wet climates, the dehusking (by pounding) of stored spikelets of glume wheats and the cleaning of the grain (by small-scale winnowing and sieving) occurs on a day-to-day basis. In such climates, this work is generally done indoors, and, indoors, the most obvious place to sweep the winnowings and dump the cleanings is into the fire burning in the hearth. Here, any light chaff is burned away; but surviving in the ashes are two classes of charred remains: firstly, wood charcoal (if wood was used as fuel); secondly all the denser components of the cleanings - as summarised in table 1 (see product no.5).

In stark contrast, accidents during parching or roasting are bound to have been rare relative to this daily accumulation of hearth ashes laced with the charred remains of cereal cleanings from steps 11, 12 and 13: primary products could scarcely have been destroyed through carelessness very often. The risk of different crop products being mixed in the same midden is further reduced in cases where the midden contents were regularly cleared out for use as manure. In such cases the accumulation of charred remains is derived from a reduced number of events (i.e. from a shorter period of hearth use), and the chances of their including an admixture of the charred products of a relatively unusual accident during, say, grain roasting, are correspondingly reduced. This situation seems to apply to the middens-cum-compost-heaps at the Romano-British site of Cefn Graeanog II (see R.B. White et al., forthcoming). It is perhaps no accident, therefore, that it is samples of relatively unmixed crop remains of precisely the same composition as present-day 'cleanings' which are being recovered with such consistency from small rural sites such as Wilderspool and Cefn Graeanog.

On the other hand, we must expect an altogether different range of charred products on larger, more complex sites, especially those with rich destruction levels in which all crop products present in the settlement at the time of destruction could have been exposed to the sort of smouldering fires typical of collapsing burnt buildings. By excluding most of the oxygen, such fires often allow even light chaff to be preserved by charring.

In destruction sites such as these, some mixing is inevitable. Despite this, where mixing occurs, it is generally restricted to **equivalent products** from different crops, e.g. it is not unusual to find a mixture of barley grain and Emmer grain - both from bulk storage.

In summary, then, a) mixing of equivalent products from different crops is not unusual; b) mixtures of entirely different classes of crop product seems to be relatively rare, except in the cases of deliberate amalgamation indicated in figs. 2, 3 and 4.

c) With non-segetal species (classes A2 - A6 below), mixing is quite usual. Thus mixtures of hazel shells (a food by-product) with remains of, say, a bedding/thatching species such as heather have occurred at a number of sites.

5. THE SORT OF QUESTIONS ANSWERABLE BY USE OF PLANT REMAINS INTERPRETED VIA ETHNOGRAPHIC MODELS

Before considering how a large and complex body of data from an assemblage of plant remains can be related to ethnographic models, it is appropriate to briefly consider the sort of questions which can be answered. However, they have been discussed in detail elsewhere, and little more than a bibliography of examples is offered here.

5.1 Was the site a 'primary producer' (i.e. farming) settlement or strictly a 'consumer' settlement?

Features of composition which can be used to distinguish between remains from 'primary producers' and, say, a pastoralist 'grain-consumer' are discussed in Hillman (1981, and to a lesser extent 1983 a). (Note: The presence of cereal grains in isolation is not conclusive evidence of local crop husbandry).

5.2 What were the functions of excavated structures in terms of activities concerned with the manipulation of plant products?

Here, the starting point is studies of 'context related variation'; i.e. studies of the relationship between variation in the composition of samples of plant remains on the one hand, and the distribution of excavated structures on the other. With the recent availability of ethnographic models of the sort outlined here and by Glynis Jones (this vol.), these patterns of variation can now be interpreted in terms of the on-site distribution of those activities responsible for generating the plant products represented in the remains.

Publications which discuss context-related variation in plant remains are numerous. They include the follwing: Buurman (1979), Colledge (forthcoming), Dennell, (1972, 1974, 1977, 1978); Hillman (1972, 1973, 1981 pp.127 & 143-4); Hubbard (1975, 1976a, 1976b, 1980); Knörzer (1981); G. Jones (1981, 1982, forthcoming); G. Jones and Rowley-Conwy (in press). The mechanics of this form of analysis are also discussed below.

5.3 Did they till their land with ards or with mouldboard-ploughs?

Discussed in Hillman 1981 (145-6), 1982. Clearly, this question is relevant only to sites post-dating the development of the mouldboard plough.

5.4 Did they sow their crops in autumn or spring?

Discussed by M. Jones (1981) and in greater detail in M. Jones (in preparation); also Reynolds (1981 a & b); and Hillman (1981).

5.5 Did they irrigate any of their crops?
- Crop types as indicators: Helbaek (1969, 1972).
- Weed floras as indicators: Charles, (forthcoming); Hillman and Colledge (in prep). + Several studies of presentday phytoecology.

Note: These last three questions (5.3, 5.4 and 5.5) are addressed archaeobotanically not by reference to ethnographic models but rather by reference to models for the ecological behaviour of key weed species (or species assemblages). They are given mention in this discussion of ethnographic models only because analyses which aim to identify specific groups of weeds can be built into the sort of analytical sequences outined below, if only as an extension of the 'D' classification system. Glynis Jones is also in the process of devising novel analytical systems specifically for extracting from weed remains information on past edaphic environments (G. Jones, this vol.).

5.6 Did they rogue (weed) their crops?

See Reynolds 1981, 1982; Hillman 1981.

5.7 Harvesting methods?

Discussed in van Zeist and Bottema (1971 pp. 537-538); Reynolds (1981, 1982); Knörzer (1967) and Hillman (1981 pp. 148-153)

5.8 Crop processing: threshing, winnowing, parching, dehusking, sieving and hand-cleaning.

The effects of each of these operations on the composition of crop products were discused by Hillman (1981) and are discussed in quantitatively defined terms by Glynis Jones in this volume. Results of laboratory experiments with sieving were presented by Robin Dennell (1972). Effects of coarse sieving detected in charred plant remains from Tell Medhur are discussed by Richard Hubbard (forthcoming). A number of these operations and their products have also been classified in accessible tabular form by Knörzer (1981).

6 APPLYING THE MODELS TO ARCHAEOLOGICAL REMAINS

We have our site; we've recovered a dozen (perhaps hundreds) of samples of plant remains; sample by sample we've sorted them and identified them to a 'point of diminishing returns' fixed,in turn, by reference to questions posed, perhaps, at the outset of excavation. How, now, do we relate the (often) thousands of identifications and scores to the models outlined above?

With small assemblages of up to, say, ten samples, any similarities in composition between each of the samples and a particular modern crop product will often be obvious from simple inspection. However, in assemblages involving large numbers of rich samples of diverse composition, similarities with modern crop products are not always obvious from inspection alone, and it is generally impossible to recognize 'by eye' any significant patterns of correlation between horizontal variation in sample composition and the various site context types. Some definable and repeatable system is clearly needed to -
a) reduce the numbers of variables without losing what could prove to be vital information,
b) extract information on husbandry and

		computer codes							
Site area			3LG. C						
provisional phasing			II						
feature			HEARTH						
feature no.			135						
catalogue/sample no.			1013 (i)	1013 (ii)	1013 (iv)	1013 (v)	1013 (vi)	1013 (vii)	1013 Σ
volume of earth floated (units: buckets)									2½ bkt.
mesh size of flot sieves (in mm)			1 + ¼	1 + ¼	1 + ¼	1 + ¼	1 + ¼	1 + ¼	1 + ¼
volume of flot (in ml)			40	230	350	210	150	70	1150 ml
volume of total charcoal									
amount of flot sorted (as vol., % or ratio)			100%	100%	100	100	100	100	100%
initials of sorter			GSW	STW/GSH	AM	AH	ES/AM	CM/AM	
Triticum dicoccum/ T. monococcum	spkt.fks.	1							
T. dicoccum (term[1].) or *T. monococcum*	grains	2							
T. dicoccum	rachis frags.	3	1						1
	spkt.fks.	4		1	1.	4.			1. 5
	gl.bases ⑦	5							
	grains	6							
T.dicoccum or *T. spelta* - - - - - - -	rachis frags.	7	1	4	1	4	1		10. 1
	spkt.fks.	8	1	15	2				18
	gl. bases ①	9	14.	31	112.	51.	23	12	
	grains	10		6 (8t)	18 (6t)			2. 1. (2t)	26. 1 (10t)
T.spelta - - - - - - - - - - - - - - -	rachis frags.	11	2	38	65.	20.	10. 1.	1. 1.	134. 1. 1.
	spkt.fks.	12	1	4. 1	9. 2.	15	3. 2.	2.	32. 5.
	gl.bases ③	13	22	57.	52. 20.	32.	15. 2.	7.	215. 20.
	gl.frags. (non-basal)	14	3	2.	3				8
	grains	15	2. (1t)	15 (4t)	13. 12. (3t)			34. 2. (11t)	64. 14 (19t)
T.spelta or *T.aestivo-compactum* - - -	rachis nodes/forks ③	16	4. (38)	3			1		8
	grains ⑤	17				2.			
T.aestivum - - - - - - - - - - - - -	rachis nodes	18							
	grains ③	19							
Triticum - indet.free-threshing spp.	rachis nodes	20							
	grains	21							
Triticum - general indet. - - - - - -	rachis frags.	22							
	gl./lemma frags. ⑥	23			7.				7.
	awn frags. ⑤	24							
	grains	25		14. 6.	23.		4.	9. (2t)	50. 6. (2t)
		26							
Triticum/ Secale - - - - - - - - - - -	grains	27							
		28							
Secale cereale - - - - - - - - - - - -	rachis frags.	29							
	grains	30			2.				
	awn frags.	31							
		32							
Hordeum sativum rachis	/6 row/lax ear (c - term. seg. dense ear) a	33	1.	1.	2.				3. 1.
	" / " /dense-eared - - - - - - - - b	34							
B = hulled	" / " /rel.lax sub-basal or rel. dense non-basal - c	35		2.		1			1. 2.
N = naked; l = lax-eared; d = dense-eared	" / " /unreferable - non-basal - - d	37			1				1
	" / " /unreferable - basal - - - - e	38			1.				1
	" /2 row/ (indicate 'a' → 'e' with score)	39							
	" /2 or 6 row/ dense eared	40							
	" / " " / lax eared	41				1			1
	" / " " /basal or rel.dense medial	42		3.				2.	5.
	" / indet. frags.	43		4.	3.				7.
	grains - assymetric	44			8. (7H)			3 (2H)	11. (9H)
	" - symmetric	45			4. (0H)			7 (7H)	11. (7H)
	" - unreferable	46		26. 5 (7H)	6. (3H)	1		6 (2H)	38. 6 (10H)
	awn fragments	47							
		48							
Hordeum sativum/Hordeum sp. (grass spp.)	grains ⑥	49							
		50							
Avena sativa	lemma bases - lower florets	51							
	" " - upper florets	52							
cf. *Avena sativa* - - -	awn frags. (non-twisted, lower half) ⑦	53							
	grains	54							
	spkt.bases (ie. pedicil tips) ⑦	56							
Avena strigosa (inc. *A.brevis*) - -	lemma bases - lower florets	57							
	- upper florets	58							
Avena sativa/A.sterilis (*upper flts.*) or *A.strigosa* (*lowerflts.*)	- lemma bases	59							
Avena fatua - - - - - -	lemma-bases - lower florets	60							
	" " - upper florets	61						1	1
Avena sterilis (inc. *A.ludoviciana*) - -	" " - lower florets (must inc. intact rachilla of upper florets)	62							
cf. " " "	" " - upper florets	63							
Avena fatua / A sterilis	" " - lower florets (lacking rachilla)	64							
	spkt.bases (ie.pedicil tips) ⑦	65							
Avena sp.indet. - - - -	lemmas or lemma frags.	66							
	awn frags. ⑦	67							
	rachilla frags.	68							
	grains - large	69			1				
	- small	70					1		
	spkt. bases (pedicil tips) ⑦	71							
? *Avena sp.* - - - - - -	inflorescence nodes ⑦	72							
		73							
CEREALS INDET.	grains (counted as no.of embryos) (no attempt made here to count tail grains separately)	74	5.	60 (6.5t)	12. 4.	1	4.	34 (9t)	114. 10 (14t)
Cereals / other large grasses	- culm bases	75			2				
	- aerial culm frags. ⑧	76			6				
	- leaf frags.	77			3				
	- rachis frags.	78							
		79							

Degree of certainty of identification is indicated by position of each score within its vertical column: scores on left = certain identifications; scores on right = dubious identifications; intermediate positions = correspondingly intermediate degrees of certainty/ uncertainty. Encircled nos. are footnotes (see sep.sheet for key). G.Hillman 1976; revised 1979.

Figure 5. EXAMPLE OF ONE SHEET OF PRIMARY SCORE TABLES USED FOR CEREAL REMAINS AT THE SITE OF CEFN GRAEANOG

processing methods, and
c) test the significance of any apparent relationships between the horizontal distribution of site contexts and the various components of variation in sample composition.

As our example, we will use the results from a site in North Wales (Britain). This site is Cefn Graeanog, a native British farmstead of the Late Iron Age and Roman Period, located on an exposed ridge of the Lleyn Peninsula in Gwynedd (NW Wales). It provides a useful example because

a) excavation revealed a wide range of clearly defined structural contexts, (see R. White, forthcoming);
b) the excavator, Richard White, recovered charred remains of plants from almost every one of these contexts (280 samples from 44 contexts);
c) the remains were quite rich: they included over 250 taxa and chaff/grain classes;
d) the site is of a type common in parts of Britain and perhaps Europe as well.

Fig. 5 is a copy of one of the cereal score sheets, and **Fig. 6** is a copy of a small section of a score sheet for the 184 non-cereal spp. identified from the site. Each vertical column represents one sample. Scores on the far left of any one column represent the number of items of certain identity, while scores on the far right represent numbers of dubious identity. Intermediate positions represent intermediate levels of certainty or uncertainty of identification. This device obviates the use of 'cf.s' and other formulae for indicating various degrees of confidence in identifications. (Explanation of other features of the scoring system will appear in Hillman, forthcoming b).

In analysing the data from the Cefn Graeanog plant remains, two strategies were open to us:

a) The first strategy would have been simply to feed into principal components analysis (P.C.A.) the separate scores of every taxon from each sample, see how the samples get grouped, and then - firstly compare the composition of samples in each of these computer-produced groups with the generalised composition of crop products in our modern models to see if the groups make any sense in agrarian terms, - secondly, test the distribution of such groups for any significant correlation with the distribution of excavated structures.

We abandoned this strategy for the following reasons: (i) We had too many variables for the matrix size of any P.C.A. programme available to us at the time. (ii) A majority of the taxa (or chaff components) were present in only a few of our samples and, treated as separate variables, would normally be unusable. Only by amalgamating scores as explained below could we avoid this loss of potentialy valuable information. (iii) P.C.A. systems tend automatically to be biased by (i.e. over-weight the significance of) isolated rarities. For example, we found that in the course of a small-scale 'trial run' the computer had separated certain samples into separate categories of their own simply because they had two seeds of Nardus stricta which was a species not present in other samples. This problem, too, could be circumvented only by the sorts of amalgamations used in the alternative strategy.

b) Our alternative strategy (and the one finally adopted) was to
- classify each taxon and each class of chaff and grain by direct reference to the ethnographic models;
- within each sample, amalgamate the scores of all items of like class from any one sample;
- eliminate all classes which, despite the amalgamations, are still represented in very few samples;
- convert class fequencies to those ratios which, from the ethnographic models, could be expected to provide answers to questions relating to husbandry and processing methods. (These ratios are thus used to characterise the key features of sample composition).
- using P.C.A.,
(i) test for similarities in composition between samples from any one phase and between samples from any one class of context (within phase) e.g. hut floors, hearths, middens;
(ii) group all related samples on this basis;
(iii) test for systematic correlation between distribution of sample groups and distribution of excavated features in any one phase of the site.
(iv) Having thus accounted for (i.e. eliminated) the major components of lateral (horizontal) variation within each phase, test for any systematic change through time (i.e. variation between phases).

computer codes

Site area	Bldg G							Blg. G					Blg G		
provisional phasing	III							III					III		
feature	DRAIN							HEARTH					HEARTH		
feature no.	82							124					89		
catalogue/sample no.	1074 a	.b	.c	.d	.g	.h	1074 Σ	1152 a	b	c	d	Σ	1125 a	b	Σ
volume of earth floated (bkts.)	2 bkts	1	½	½	2	1	7	1 bkts	1	1	1	9	3 bkts	1	4
volume of flot (ml)	225	15	< 5	< 5	580	62	1132	238	490				24	45	69
sieve mesh diameter (mm)	1 + ¼							1 + ¼					1 + ¼		
flot sorted by (initials)/% sorted	AM/100%	AM/100	..	..	..	100%	..	AM/100	AM/100	AM/100	SM AM/100	JCL	CH AM/KD	..	..
101 Pteridium aquilinum - immature frond frags.															
102 P. aquilinum - mature frond fragments [2]	18.	17.			31.	1.	67.						1.		1
103 Ranunculus acris/repens/bulbosus						.1.	.1								
104 Ranunculus flammula					3.1.		3.1.								
105 Caltha palustris	.1						.1								
106 Papaver rhoeas - stigmatic disks [3]															
107 Viola sp. (small seeded spp.)															
108 Brassica sp./ Sinapis arvensis - seeds															
109 " - capsule frags.															
110 Rorippa islandica															
111 Hypericum sp.	1.						.1.								
112 Lychnis flos-cuculi															
113 Stellaria media type	4. 4.	5.			9. 5.		22. 9.								
114 Spergula arvensis	9.	3.			19.	3.	34.	1.	3.	1.	1.	6.	1.		1.
115 Montia fontana															
116 Scleranthus perennis															
117 Chenopodium album	1.						1.								
118 Chenopodium murale					1. 1.		1. 1.								
119 Chenopodium sp. (gen. embryos only)						.1.	.1.						1.		1.
120 Atriplex sp.		1.					1.		1.			1.			
121 Ulex sp. - leaves & spine tips			2.		1.	1.	4.	5.	7. 1.			12. 1.			
122 " - seeds					.1		.1.								
123 Ulex/Genista - indet. seeds	.1.		1.				1.1.			3.		2.			
124 Genista tinctoria						.1.	.1.								
125 Genista tinctoria/anglica										1.		1.			
126 Trifolium arvense type					.1	.1	.2.								
127 T. repens (or ? T. hybridum)		2.			2. 1.	3. 1.	7. 2.		.1.			.1.	1.		1.
128 T. medium / T. pratense (or ? Medicago sat.)					.1. 1		.1 .1								
129 Trifolium sp.	.1					.1.	.2.								
130 Lotus pedunculatus															
131 L. pedunculus/corniculatus	1.					.1	1. .1.								
132 Stellaria graminea	2.	1.			8. 2.		11. 2.								
133 Vicia/Lathyrus (indeterminate)	1				.1.		1.1.			.1.	.1	2.	1.		1.
134 Medium-sized legume - round indet.	1. 1.				1.		2. .1.				1.	1.			
135 " " " - flat indet.															
136 Potentilla palustris	1.						1.								
137 Fragaria vesca															
138 Rubus idaeus	.8.1.	.4.			.6.		.18. 1.								
139 Rubus fruticosus agg.	1.						1.								
140 Rosa sp. - achenes															
141 - spines															
142 Prunus spinosa					2.		2.								
143 Hydrocotyle vulgaris															
144 Apium sp. (A. graveolens type)															
145 Umbelliferae indet.										.1		.1			
146 Euphorbia sp.															
146 Polygonum aviculare					4.		4.								
147 P. persicaria	5. 1. 1	2. 1.			7. 1.		14. 2. 2		.1.	1.	1	2. 1.		1. 1.	1. 1.
148 P. lapathifolium (inc. P. nodosum)					3		3				1	1.			
149 P. hydropiper	1.	1. 1.			8. 2.		10. 3.								
150 P. hydropiper/mite		.2			3.	3	6. 2								
151 P. mite	1.						1.								
152 P. mite/persicaria															
153 P. minus		.1.					.1.				1.	1.	1.		1.
154 P. convolvulus	.1	1. 1.			1. 3.		1. 5.			1.	5.	6.			
155 Polygonum indet. (kernals only in most)	3.	.1			6.	7.	16.1.								
156 Rumex acetosella	10				8. 4.	7.	25. 4.			2.	2.	4.			
157 R. conglomeratus/sanguineus/acetosa	138. 11.	159. 7.			345. 18.	25. 4.	667. 42.		.1.			1.	2. 1.		2. 1.
158 Rumex indet. - medium	.1.				16. 2.	.1.	16. 5.								
159 Stellaria holostea					2.		2.								
160 Urtica dioica					4. 2.	.1	4. 3.								
161 Salix alba															
162 Salix caprea															
163 Coylus avellana (nos.= whole fruit s)										1.		1.	1.		1.
164 Calluna vulgaris - flowers or fl. buds					.12.		.12.		28.			28.			
165 - immature capsules	36.	3. 2.		1.	21.		61. 2.		115	17.	46.	130.	5		5
166 - shoot apices or free lvs.	1		3.		5.		9.		336.	2.	7.	246.			
167 Erica tetralix - fls. or immat. ovaries															
168 - shoot apices or leaves									3.	1.		4.			
169 Erica cinerea - seeds	11.						11.								
170 - fls. or immat. ovaries	1						1.						2.		2.
171 - shoot apices or leaves															
172 Vaccinium myrtillus		1.					1.								
173 Ericaceae - indet. ovaries or capsules	1.					1.	2.								
174 Empetrum nigrum															
175 Anagallis sp.															
176 Aphanes microcarpa	1.						1.								

Fig. 6. EXAMPLE OF ONE SHEET OF PRIMARY SCORE TABLES USED FOR NON-CEREAL REMAINS AT THE SITE OF CEFN GRAEANOG

Scores = numbers of items identified. Scores on left of columns - certain identifications; those on right = dubious identifications. (All footnotes appear on separate sheet).

Each of these analytical steps will now be discussed in more detail.

6.1 CLASSIFICATION OF REMAINS (AT CEFN GRAEANOG)

STEP 1: CLASSIFICATION OF EACH SPECIES BY THE PROBABLE MODE OF ARRIVAL OF ITS SEEDS ON THE SITE

This classification does not draw directly on the ethnograhic models outlined above and is necessarily highly subjective. However, it is an unavoidable first step.

(see table 2 - below)

Different sites will clearly require different systems of classification, depending on which species are represented in the remains. At Cefn Graeanog, for example, a diverse range of modes of arrival (i.e. types of usage) had to be grouped under the single class (A2) simply because large numbers of Calluna (heather) seeds, capsules and flowers were recovered from the site, and they could have come from plants which had been used either as bedding (for humans or animals) and/or as fodder and/or as fuel and/or as thatching. As many as possible of these different products therefore had to be included in the one class (A2). Similar constraints forced us to amalgamate four disparate product types within another of the classes (A3), and this class consequently incorporates as diverse a mixture as class A2.

Assigning any one species to a single class was problematic, even when the classes are as broad as some in this classification which was developed for Cefn Graeanog. Most difficult of all was deciding which of the 184 species were likely to have been segetals (i.e. weeds of crops). The nature of our dilemma is perhaps apparent from table 3 on the next page.

(see table 3 - next page)

Table 3 represents a small segment of the full classification of all 184

Table 2. CLASSIFICATION SYSTEM A: MODE OF ARRIVAL OF SEEDS ONTO SITE

(Note: The composition of each class was determined by which species were recovered from the site (in this case, Cefn Graeanog). Other sites will require different classes).

A1: seeds, chaff, grain etc. arriving as components of crop products, i.e. items brought in with the harvested sheaves, separately harvested ears or straw.

A2: seeds from non-cultivated plants gathered as fodder (inc. hay), bedding and fuel (though excluding species represented only by wood charcoals).

A3: seeds from plants gathered as foods, condiments, medicines or dyes.

A4: seeds from plants gathered as 'furnishings' such as rush-matting or reed-thatching.

A5: seeds derived from peat or dung burned as fuel. Such seeds are probably rarely preserved at this site.

A6: seeds arriving casually (i.e. non-systematicaly) by other means; e.g. seeds adhering to fleeces, hooves or feet (the 'welly-boot effect'), dead ruderals cut as tinder, seeds from flowers brought in as decoration, etc. (Although many spp. could be classified under A6, more specific categories were sought whenever possible as there is a low level of probability that any given seed had arrived on site by these means).

Table 3. SMALL SECTION OF ONE OF THE GENERAL CLASSIFICATION TABLES OF SPECIES IDENTIFIED IN CHARRED REMAINS FROM THE SITE OF CEFN GRAEANOG

Note: The only species which were used in subsequent analyses were those for which only <u>one</u> of the alternative classifications (within any one of the systems A,B,C or D) were probable. (The less probable alternatives are given in brackets). On this basis, therefore, both Hypericum and Lychnis were immediately deleted from further analysis.
Where no unbracketed B or C class$^{n.}$ is offered, the plant was probably not a segetal. Where no unbracketed D classification is offered, the plant was quite possibly a segetal, so a firm 'D' classification would be misleading.

computer code for each species	species identified in remains	classification systems A	B	C	D
111	Hypericum sp. or spp.	A2 A6	(B3 B1)	(C3)	(D1)
112	Lychnis flos-cuculi	A1 A2 (A5 A6)	(B3)	(C3)	(D2 D4)
113	Stellaria media	A1 (A6)	B3	C4	
114	Spergula arvensis	A1	B3	C3 (C4)	(D1)
115	Montia fontana	A1 A5 A6	(B3)	(C4)	D4
116	Scleranthus perennis	A1	B3	C4	(D1)
117	Chenopodium album	A1(A3 A6)	B3	C3	(D1)
118	C. murale	A1(A3 A6)	B3	C3 (C2)	(D1)
⋮					
161	Salix alba	A6 (A5)	-	-	D4 D1
162	Salix caprea	A6 (A5)	-	-	D4 D1
⋮					
164-6	Calluna vulgaris (seeds, lvs., fls.)	A2 (A5)	-	-	D2 D3
167-8	Erica tetralix (lvs., fls.)	A2 (A5)	-	-	D2 D3
169-71	Erica cinerea (seeds, lvs., fls.)	A2 (A5)	-	-	D2 D3

(The full table of classifications of all species identified at Cefn Graeanog will appear in Hillman, forthcoming b).

non-cereal spp. at Cefn Graeanog using all four (A to D) of the classification systems discussed in this paper.

In table 3 it may seem strange that plants of marsh or damp meadow such as Lychnis flos-cuculi and Rorippa islandica, should be assigned a segetal classification. This reflects the fact that, in this system, all species identified in the site remains are classified according to the way their seeds probably got onto the site, and not according to local habitats in which they may have been most prolific. An example is needed here. At Cefn Graeanog, the land most likely to have been cultivated ran down into a mire. As a result, the lower ends of the fields were probably marshy (as they are today) and heavily invaded by a wetland weed flora including plants such as R. islandica and L.flos-cuculi. Even though such plants would inevitably have been more abundant in the adjacent mire (they still thrive there today), their charred seeds recovered from the site were consistently mixed with crop cleanings and are likely to have arrived as crop contaminants. It is for this reason that wetland plants of this type were classified firstly under A1 (and only secondarily under A2, A5 and A6, see table 3). On the other hand, plants such as **Caltha palustris** and **Carex pauciflora** which are typical of even wetter habitats seem less likely to have survived as weeds of wet arable land. However, invasion by wetland spp. has been observed even in arid areas. For example, seeds (mericarps) of Alisma lanceolata were identified in 'fine sievings' from the processing of crop products from an unirrigated wheat field at Aşvan (E. Turkey). This occurrence seems explicable only on the basis of occasional plants having invaded wet patches in the field adjacent to water -channels. But while many perennials can, indeed, survive cultivation so long as the land is only lightly tilled with an ard (see Hillman 1981, 145 - 6), the presence of Alisma in these crop products must surely represent an an extreme case, and Alisma would never normally be classed as a segetal.

Distinguishing between segetals and ruderals may appear to be even more problematic. However, precisely the same principal applies here as it does for the wetland species discussed above. Once again, charred seeds of typically ruderal species found consistently in association with crop 'cleanings' are likely to have arrived on the site (and got into fires) primarily as contaminants of crop products; they are far less likely to have arrived via one of the 'casual' routes grouped under class A6 (see table 3). In most cases, therefore, typically ruderal species are assigned to class A1 as the mode of arrival offering the most plausible explanation for their seeds getting onto the site and into fires. (One exception here is **Urtica dioica** which I have never observed as a segetal, even under the lightest ard cultivation).

All probable segetals (i.e. all species with a relatively unequivocal A1 classification) can now be further classified under the 'B' system. Of the examples given in table 3, therefore, the species that could be carried forward into the 'B' classification were - **Stellaria media**, **Spergula arvensis**, **Scleranthus perennis**, **Chenopodium album** and **C.murale**.

STEP 2:
SYSTEM B: SUB-CLASSIFICATION OF CROPS AND SEGETAL WEEDS (FROM CLASS 'A1' ABOVE) BY THE TYPE OF CROP PRODUCT OR BY-PRODUCT IN WHICH EACH ITEM IS NORMALLY FOUND.

This step effects a sub-division of those species which were classified under class A1 in the preceding step. Here, then, each segetal weed seed and each cereal component identified in the site remains is now assigned to a particular crop product. These assignments are made strictly by reference to the ethnographic models summarised above, and the overall objective is to discover which processing stages are represented on the site. Of the weed species, the only ones used are those with a relatively unequivocal A1 classification in the preceding step (step 1). And of the crop products, only those listed in table 1 are considered here. This 'B system' classification is summarised in table 4.

(See table 4 - next page)

a) classification of **crop remains** under the B system:

The major components characterising each of the crop products likely to be preserved in charred form on archaeological sites were outlined in table 1. The basis for assigning any one cereal component such as glume bases to a particular product was the relative abundance of this component in the seven different products summarized in this same table 1. On this basis, however, the only components which could be assigned a fairly unequivocal 'B' classification (and therefore be used in subsequent analyses) were those which were conspicuously abundant in only one class and relatively rare in all others. Any component that was fairly common in two or more different products therefore had to be deleted. As an example of the mechanics of this system, table 5 shows the 'B' classes (i.e. crop product classes) to which just 15 of the cereal components were assigned. (The full range of 78 types of cereal component found at Cefn Geaeanog are listed in the primary score sheet reproduced as fig.5, above).

(See table 5 - next page)

Table 4. SYSTEM B: CLASSIFICATION OF CROPS AND SEGETAL WEEDS BY CLASS OF CROP PRODUCT WITH WHICH EACH ITEM IS GENERALLY ASSOCIATED IN PRESENT-DAY TRADITIONAL AGRICULTURE

Note: For the purpose of this table, only glume-wheat products are considered and of these, only those that are likely survive in archaeological sites (as listed in table 1).

B1: winnowing waste (products of steps 4, 5, & 10 in fig.3).

B2: 'cavings' waste from coarse sieving from steps 6a and 11 in fig.3 (with or without 'chob' from step 13a in fig.4).

B3: cleanings from fine sieving (from step 12 in fig.3, and step 13b in fig.4).

B4: semi-clean prime grain etc. (from accidentally burned grain stores in dry areas).

B5: cleanings from hand-sorting (from step 14 in fig.4).

B6: pure prime grain (probably mainly from step 24 in fig.4).

Two additional products occur in charred form on archaeological sites, these are products 1 and 3 in table 1. However, they are omitted here as their composition is effectively a combination of two or more of the products listed. (In the text, the first of these is coded as B$\sum$).

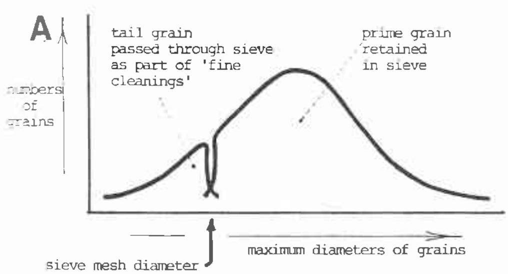
Table 5. EXAMPLE OF MECHANICS OF STEP 2 OF CLASSIFICATION UNDER THE 'B' SYSTEM: PART OF A TABLE OF CEREAL REMAINS FROM CEFN GRAEANOG CLASSIFIED ACCORDING TO THE CLASS OF CROP PRODUCT WITH WHICH EACH ITEM IS USUALLY ASSOCIATED IN PRESENT-DAY CROP PRODUCTS

't' = tail grains. 'p' = prime grains. These were scored separately (see fig.5, above) as were the 'unreferable' grains of intermediate size which cannot be assigned to specific crop products and which do not appear here.

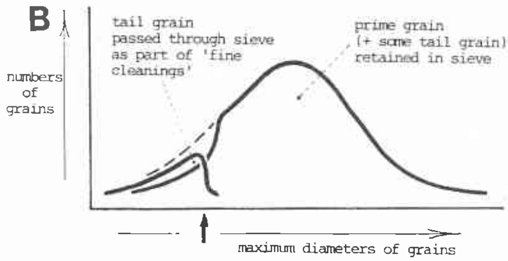
		computer code	class of products with which norm--ally associated
T. dicoccum or T. spelta:	rachis fragments	7	B3 (B5)
	spikelet forks	8	B3 (B5)
	glume bases	9	B3 (B5)
	grains	10	p:B5; t:B3(B5)
T. spelta..................	rachis fragments	11	B3 (B5)
	spikelet forks	12	B3 (B5)
	glume bases	13	B3 (B5)
	glume frags.(non-basal)	14	B1 (B3)
	grains	15	p:B5; t:B3(B5)
T.spelta or aestivo-compactum	rachis nodes/forks	16	B3 (B5)
	grains	17	p:B5; t:B3(B5)
T. aestivo-compactum.......	rachis nodes	18	B2 (B1.B3)
	grains	19	p:B5; t:B3(B5)
Triticum sp. (indet.naked sp.)	rachis nodes	20	B2 (B1.B3)
	grains	21	p:B5; t:B3(B5)
etc.		etc.	etc.

Tail grain vs. prime grain:
Barring two products (nos.1 and 3 in table 1) which are rarely found in charred form at primary producer sites, remains of grains are characteristic of two products: firstly, cleanings from fine-sieving (product B3) which contain tail grain; secondly, product B5 which consists of semi-clean prime grain with a minority component of tail grain. Distinguishing tail grain from prime grain can therefore contribute to the identification of product type. However, distinguishing tail and prime grain requires knowledge of mesh sizes of the fine sieves used, because it is during fine-sieving (stages 12 and 13) that much of the tail grain is unavoidably eliminated from the prime grain along with small weed seeds and glume-bases.

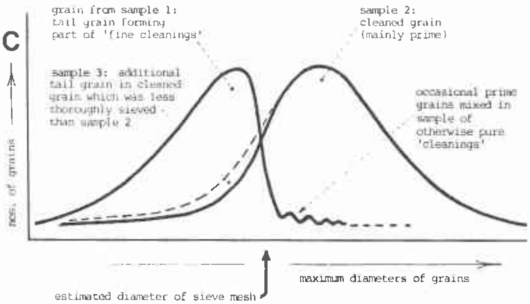
Clues to the mesh diameters of the sieves used can, in fact, be extracted from measurements of the maximum diameters (breadths) of the grains present in uncontaminated samples of 'fine cleanings'. The grain in fine cleanings is exclusively tail grain, of course, as there is no way that large, prime grains could have passed through the fine sieve. If, therefore, the original frequency distribution of maximum grain diameters was orinally of Gaussian form, then thorough sieving with meshes designed to allow the elimination of most of the smaller weed seeds should **theoretically** result in the loss of most of the tail grain as well. The theoretical effect on a single batch of grain from bulk storage would then be as follows:



However, sieving is rarely that thorough, and not all those items which could theoretically pass through the sieve are, in practice, eliminated. In other words a variable proportion of the tail grains remain with the prime grain. A more realistic representation of the effects of sieving on the frequency-distributions of grain sizes in a single batch of grain is therefore as follows:



In examining archaeological remains, however, it is usual to measure equal numbers of grains from each of the different samples, regardless of whether they were recovered from middens or granaries. Thus, when **equal numbers** of grains are measured from samples of cleanings on the one hand and samples of prime grain on the other, then the frequency distributions inevitably appear to exhibit a rather different relationship to each other than that illustrated above:



The approximate diameter of the sieve mesh used can then be estimated as indicated. (Clearly, sieve mesh sizes cannot be deduced from any part of the prime grain curve).

At Cefn Graeanog, it proved possible to estimate mesh diameter as indicated above from one ± pure sample of charred remains of 'fine sievings'. This estimate was then used as the basis for identifying all other grain (from the same phase of occupation) as either 'tail' or 'prime'. Only those grains well above or below the estimated mesh diameters were, in fact, referred to either class; the rest were left as 'unreferable' (see example of score sheet, fig.5). It must be stressed, however, that on many sites, **slight** contamination of 'cleanings' is not uncommon: there are sometimes small admixtures from other products, and these admixtures commonly include a little prime grain. These prime grains inevitably produce even greater overlap between the two frequency distributions in diagram 'C' above.

(b) 'B' SYSTEM CLASSIFICATION OF WEED SEED REMAINS:

From our studies of present-day crop products, it was clear that the principal factors determining what seeds were present in any one crop product were (i) the ratio of their surface area to weight (i.e.their winnowability), (ii) seed size (i.e.sievability), (iii) seed 'headedness'. Each of these categories and their use in charred remains will now be considered in turn:

(i) Winnowability
For any given wind strength, the probability that a seed can be winnowed out of the prime products seems to depend primarily on the ratio of its surface area to its weight ($mm^2.g^{-1}$). This ratio tends to increase with decreasing size with the result that winnowing tends to eliminate very small seeds such as those from Campanula species. The presence of wings on the seeds also increases surface area, of course; winnowing consequently eliminates the winged seeds of plants such as **Linaria vulgaris** and **Rhinanthus serotinus** as well as the winged fruits of **Artedia squamata, Aellenia autrani** and several species of **Scabiosa**. At Cefn Graeanog, therefore, any charred remains of winged or very small seeds and fruits of segetal species were classified as winnowing waste. (Such seeds were, in fact, very rare).

(ii) Sievability
Seed size is important in that it determines not only 'winnowability' at the bottom of the size range, but also 'sievability' in the upper size ranges. This effect is reflected in the clear-cut correlation between the major products and the sizes of the seeds contained in them, as indicated in table 1. On the basis of this correlation, seeds and fruits can be grouped into four sievability/winnowability classes, each of which is characteristic of a single class of crop product. (These 4 classes are outlined in table 6). Clearly, therefore, the identification of charred remains of these particular products is very straightforward so long as they are not mixed: it is merely a matter of observing the size of the seeds and noting whether or not they show any signs of having once had wings. (Charred wings commonly break off).

(See table 6)

(iii) 'Headedness'.
Many of our most common weeds produce their seeds in capsules or capitulae (heads), e.g. **Papaver** spp., **Gypsophila pilosa, Vaccaria pyramidata, Cephalaria** spp., **Circium** spp., **Anthemis** spp., etc. Many of the seeds in these capsules or capitulae are released only in the course of processing. This is particularly the case if the capsules are immature at the time of harvesting, and in such cases the released seeds often show clear signs of immaturity, even when they are charred. Indeed, if, after winnowing, the threshed spikelets are cleaned thoroughly with a medium-coarse sieve (stage 6b in fig.3), then almost all the free seeds found in ensuing crop products and by-products necessarily derive from capitulae or capsules of about the same size as spikelets. A large proportion of them also show signs of immaturity. The point at which these seeds are liberated from immature capsules is stage 9 (fig.3) when the parched spikelets are pounded in order to release the grains. The effect of this liberation of seeds on the composition of ensuing products is indicated diagrammatically in table 1 (see small crosses in the last four columns). Most of the liberated seeds are eventually separated from the prime grain in stages 12 and 13 as usual. Light fragments of capsule wall are eliminated by the second winnowing - stage 10 .

An equivalent release can occur with seeds in the 'winnowable' category in cases where they have been retained in immature heads or capsules (e.g. in immature **Scabiosa** heads or **Campanula** capsules). These seeds will again be released in stage 9 (pounding of spikelets). But in this case, they are separated from the grain along with the 'light chaff' during the 2nd winnowing (stage 10)- as indicated in fig.3. (See also footnote 3 of this same figure). Theoretically, the retention of winnowable seeds in heads suggests (as explained by Glynis Jones in this volume) that the two parameters - 'winnowability' and 'headedness' should not be used

TABLE 6. 'B' SYSTEM CLASSIFICATION OF WEED SEEDS : SIZE AND WINGEDNESS GROUPS CLASSIFIED BY B CLASSES AND THE TYPES OF CROP PRODUCT IN WHICH THEY ARE NORMALLY FOUND

a). Unwinged seeds/fruits whose narrowest Øs are significantly >Ø of largest prime grain (but not much > spikelet width).* e.g. Tordylium, Aristolochia, Gundelia.	B2	'coarse sievings' from step 11 (and 6b)
b). Unwinged seeds/fruits whose max. Øs are within range as widths of prime grain. eg. Agrostemma, Cephalaria syriaca, infected grains of Lolium temulentum.	B4 & B5	'hand sortings' from stage 14.
c). Unwinged seeds/fruits whose max.Øs are significantly <Ø of smallest prime grain but >0.5 mm. e.g. Vaccaria pyramidata, Sinapis arvensis, Gypsophila pilosa, Polygonum aviculare.	B3	'fine sievings' from 12 and 13b.
d). Winged seeds (all sizes) & all seeds <0.5 mm Ø. e.g. Artedia, Campanula, Filago, Calamagrostis.	B1	'winnowing waste' from 5 and/or 10.

The weed seeds of the last class (B1) do not appear in table 1 because seeds and fruits in this category rarely survive burning and are practicaly never found in charred form on archaeological sites.

* The largest indehiscent fruits (e.g. some Umbelliferae carpels) are separated with the coarsest sievings from step 6a. However, they are so rare that they are given no separate class of their own.

TABLE 7. CLASSIFICATION OF INTACT WEED-HEADS BY SIZE AND BY THE 'B' CLASSES AND CROP PRODUCTS IN WHICH THEY ARE NORMALLY FOUND.

1. Heads significantly wider than broadest spikelets; e.g. the larger Circium spp., Carthamus spp.	B1	coarsest 'cavings' (from step 6a)
2. Heads of widths within range of prime spikelet widths; e.g. small Papaver dubium, Vaccaria pyramidata, Silene conoidea, small-headed thistles such as Carduus tenuiflorus, most of smaller Anthemis heads.	-	prime spikelets in storage or in process of being parched. (see product 3, fig.5)
3. Heads significantly narrower than smallest prime spikelets; e.g. small Papaver argemone capsules, Gypsophila pilosa capsules, Silene otites, some of smallest Anthemis heads, etc.	B2	'cavings' from 6b.

Any heads that remain unbroken after pounding (stage 9) are separated as part of the 'cavings' by-product from stage 11. The stigmatic disks of Papaver capsules often survive pounding and are separated either with the light chaff from the 2nd winnowing or with cavings from stage 11.

independently. In practice, however, winnowing waste is very rare in site deposits (hence its exclusion from table 1). Even if light chaff rich in 'winnowable' immature seeds were recovered, there would be no problem in distinguishing it either from the coarse winnowing waste of the first winnowing (stage 5) or from any other crop product.

As for the pattern of occurrence of the intact 'weed heads' themselves in the major crop products, our studies of present-day products suggests that this is a function of sieve mesh-diameters. As mesh-diameters, in turn, are carefully fixed by the sieve makers to match grain and spikelet widths, it is reasonable to take a 'short cut' and classify the weed heads by their size relative to the breadths of spikelets and grains present in contemporaneous deposits. In this way, the heads are thus automatically classified according to the crop products in which they are likely to be found following sieving. This classification is outlined in table 7.

(See table 7 - previous page)

It should be noted that the classification of weed heads in table 7 does not make use of their absolute size. Instead, it merely uses their size relative to the width of prime spikelets. Such a classification is therefore easily applied to weed heads in charred remains: it merely requires the width of the weed heads to be compared with the width of any spikelets (or well-preserved spikelet forks) recovered from contemporaneous deposits. (A more exact approach to quantification of 'headedness' is presented by Glynis Jones in the following paper).

At the site of Cefn Graeanog, this 'B' classification system was applied to every cereal fragment, segetal weed seed and segetal weed head from every sample of charred remains recovered from the site. Analysis of class totals (as outlined below) revealed many of the samples to be dominated by remains of specific crop products of types still to be found in the present day. The sort of notation used in the 'B' classifications which were applied to these remains was illustrated in table 3, above.

STEP 3.

SYSTEM C: FURTHER CLASSIFICATION OF SEGETAL WEEDS (FROM CLASS A1, ABOVE) BY THEIR GROWTH HABIT AND HEIGHT WHEN GROWING IN CROP STANDS

This step represents a further subclassification of the segetal weeds already assigned to class A1. Our objective, here, is to extract information on the harvesting methods applied to the crops represented in the charred remains from the site.

(See table 8 - facing page).

While twining habit is a relatively absolute criterion, classification of weeds by the height at which they form fruits can be rather arbitrary. Firstly, the height of any one weed species varies dramatically in response to factors such as soil-water availability and density of the crop stand. It furthermore seems unlikely that these factors consistently affect the height of the host crop by precisely the same amount. Secondly, weed heights are expressed relative to an 'average' crop height (see note to table 8), and even under a standard set of conditions, it is possible to observe enormous differences in the average heights both within one population as well as between different varieties of any one crop species. For example, some of the shortest present-day Turkish Emmers barely exceed 60 cm., while the tallest exceed 150 cm. It is impossible to be certain, therefore, whether or not reaping high on the straw of an ancient crop would have included heads of, say, Agrostemma.

Because of these uncertainties (especially in assigning certain species to C2 or C3), the 'C system' classification is, I feel, to be regarded as no more than an optional (and sometimes dubious) supplement to the A and B systems described above. Certainly, identification of harvesting by uprooting, at least, is perhaps better attempted by use of the presence of cereal culm bases (see fig.5 below). (For examples of 'C system' classifications, see table 3).

Identification of reaping heights from charred remains is also discussed by van Zeist (1968), Glynis Jones (1979), Hillman (1973 and 1981), and Reynolds (1981).

TABLE 8. SYSTEM C: CLASSIFICATION OF SEGETAL WEEDS (FROM CLASS A1) BY THEIR GROWTH FORM AND HEIGHT WHEN GROWING IN CROP STANDS.

Note: weed heights are expressed relative to supposed height of the host crop, as it is this relationship which determines which weeds get harvested. The example used here is an 'average' crop of Spelt wheat. 'Weed height' is taken as the highest point at which the plant forms fruits.

C1: twining weeds	These are automatically harvested when crop is uprooted or when reaped either low or at medium height on the straw; e.g. Polygonum convolvulus.
C2: free-standing weeds -	3/4 height of crop or taller: These are harvested by medium and low reaping; also by reaping high on straw when this is done carelessly; e.g. Agrostemma githago, Gypsophila pilosa, etc.
C3: free-standing weeds -	1/4 to 3/4 height of crop: These are harvested (together with C2 weeds) when the crop is reaped fairly low on straw; e.g. Anthemis cotula, Bupleurum rotundifolium, Papaver dubium, etc.
C4: free-standing weeds -	$<$ 1/4 height of crop: These are harvested only by very low reaping or by uprooting when this is perform- without thorough 'root beating'; eg. Aphanes microcarpa, Polygonum arenastrum (prostrate forms), Galium articulatum, Aristolochia clematitis.

STEP 4:

CLASSIFICATION OF NON-SEGETAL SPECIES (i.e. CLASSES A2 TO A6) BY THE HABITAT IN WHICH THEY PROBABLY GREW.

All species other than crops and their probable weeds were next classified according to the sort of habitat from which they were likely to have derived in the catchment of this particular site (Cefn Graeanog). Only those species assigned to classes A2 to A6 were used in this step of the analysis; i.e. we used only those species which were unlikely to have been able to survive as weeds of crops (see sect.6.1, step 1, above). Such plants probably arrived on the site direct from non-arable habitats in the area and may therefore offer clues to the types of vegetational resources available in the area of the site during its occupation.

The objective of this step in the analysis is therefore to allow amalgamation of records of plants of like habitat with a view to extracting information on past patterns of exploitation of the plant resources provided by each habitat type.

By reference to present-day vegetation in the area of Cefn Graeanog today, it seemed that the assumed non-segetal species present in charred remains from the site could be crudely divided into four groups as follows:

D1: - weeds of waste land (ruderals);
D2: - pasture or heath species;
D3: - plants of cleared woodland or woodland fringes and glades; &
D4: - marsh and bog species.

However, none of these classes are mutually exclusive, and it was eventually decided that the particular species represented in the Graeanog remains offered no possibility of distinguishing between habitats D2 and D3, for example. This dilemma is perhaps apparent from the few examples of 'D' classification offered in table 3 (above), and in table 11 (below) in which classes D2 and D3 have been amalgamated.

It will be apparent that this step (4) makes no use of ethnographic models. Step 4 is included in this paper merely because its omission would have left a gap in the logical sequence of analysis.

The following operations (6.2 to 6.4) were next applied to **each sample separately:**

6.2 AMALGAMATION OF SCORES OF THOSE CHARRED REMAINS ASSIGNED TO THE SAME CLASS

At the site of Cefn Graeanog, the charred remains were classified as outlined in the preceding section (6.1). Within each sample of charred remains, the 'scores' (numbers of items) of all those taxa assigned to any one class under the A, B, C or D classification systems were next amalgamated to give 'class totals' as indicated in tables 9, 10 and 11 (below).

Reasons for amalgamating scores:
At Cefn Graeanog, most taxa (considered individually) were present in so few samples that, in isolation, there was little sense in using their pattern of occurrence to indicate differences in human manipulations of the wild or domestic plant products concerned. This problem of 'patchy' results is not unusual on small, farmstead sites, and at Cefn Graeanog it was overcome only by amalgamating (within any one sample) the scores of those taxa or chaff classes which, on the basis of present-day parallels, could be assumed to have shared a common relationship with any given human activity. In other words, in each sample, we amalgamated the scores of all those taxa assigned to any one of the A, B, C and D classes outlined above.

These amalgamations had two principal effects: a) Any one class (within which scores were amalgamated) was represented in many more samples than were any of its constituent taxa. b) The class totals for any one sample were, of course, much larger than the scores for individual taxa. As a result, differences between archaeological samples in respect of class totals were far more likely to reflect genuine differences in human activities. In interpreting the composition of samples of charred remains in terms of human activities, we therefore used class totals and not the potentially misleading scores of individual taxa and chaff types.

(Note: the scores of individual taxa have nevertheless been retained in the form of 'primary score sheets' for special points of interpretation. All primary score sheets will be published as an appendix to the final report on the site).

See tables 9, 10 and 11

Table 9
In this table ('cereal totals') only a 'B system' classification is given, as all cereals automatically belong to class A1 and never to classes A2 to A6 (see table 2). The 'C' and 'D' system' classifications are also irrelevant to cereals. In each of the 'B' classes of table 9, the only cereal components included in class totals were those which, in the present day, are abundant in only one of those crop products commonly preserved by charring. We can consequently assume that these components are characteristic of only one of the 'B' classes listed in table 4. All other cereal components were deleted from further analysis.

Table 10
This table shows the layout of a 'class totals sheet' for those species identified at Cefn Graeanog which could be unequivocably assigned to specific 'A' classes. The table also shows how, 'B' and 'C' class scores are totalled within class A1. (Classes 'B' and 'C' are effectively sub-divisions of class A1). At Cefn Graeanog, there was only one entry in class B2, namely - intact heads of **Anthemis cotula**. This plant regularly grows to heights which embrace both classes 'C3' and 'C4', and it was therefore pointless to create columns for 'C' sub-divisions within class 'B2' in this case.

In class 'B1' there were just two entries - **Papaver** capsule fragments and **Avena** pedicil tips. These plants represent just two of the four available height classes, and the other two height classes were therefore omitted from the sub-divisions of 'B1'. There remained a number of species which had almost certainly been segetals (class A1) but which could not be assigned to specific 'B' or 'C' classes. These species were entered in a separate 'A1*' column so that , despite their uncertain 'B' and 'C' classification, their score totals could nevertheless contribute to the grand total for class 'A1'.

For each sample of plant remains from the site, the scores of the species assigned to any one class were summed as indicated at the bottom of tables 9 and 10. The 'A1' total was obtained by

Table 9. CEREAL TOTALS AT CEFN GRAEANOG: AMALGAMATION BY THE CLASS OF CROP PRODUCT IN WHICH EACH COMPONENT IS NORMALLY FOUND IN THE PRESENT-DAY: EXAMPLE OF TYPICAL TOTALS SHEET FOR A SINGLE SAMPLE

Note: The amalgamations in this table are repeated for each sample separately. The only cereal components included in these summations are those which are generally abundant in only one of the major crop products commonly preserved by charring. Class B4 is omitted here as it is equivalent to a combination of classes B5 and B6.

class of product in which each component is commonest
(To save space, each component is listed by only its computer code as given in fig.5)

B1 winnowing waste ('straw waste')	nos. pres -ent	B2 'cavings' from coarse sieving	nos. pres -ent	B3 cleanings from fine sieving	nos. pres -ent	B5 cleanings from hand sorting	nos. pres -ent	B6 clean prime gr. ready for cook[g].	nos. pres -ent
wheats 14	xx	wheats 18	xx	wheats 1	xx	None found at Cefn Graeanog		wheats 2 (prime gr.	
23	xx	20	xx	(tail gr.	xx			6 only)	
				only)	xx			10 "	xx
barleys 33	xx	cereals indet. 75	xx	2 "	.			15 "	xx
34	xx			3 "	.			17 "	xx
35	.			4 "	.			19 "	xx
37	.			5 "	.			21 "	xx
39	.			6 "	.			25 "	xx
(a-d)	.			7 "	.			27 "	xx
49	.			8 "	.				
41	.			9 "	.			ryes 30 "	xx
43	.			10 "	.				
	.			11 "	.			barley 44 "	xx
cereals indet. 77	xx			12 "	.			45 "	xx
				13 "	.			46 "	xx
				15 "	.				
				16 "	.				
				17 "	.				
				19 "	.				
				21 "	.				
				22 "	.				
				25 "	.				
				27 "	.				
					.				
				rye 30 "	.				
					.				
				barleys 44 "	.				
				45 "	.				
				46 "	xx				
Class totals (for this one sample) →	xx		xx		xx				xx

adding the 'B' sub-totals, and these, in turn by adding 'C' class sub-totals. The 'C' class totals were, however, obtained by adding the sub-totals from columns of similar 'C' class from each of the 'B' clusters; i.e. we added the sub-totals from each of the C2 columns; likewise from each of the C3 columns, etc. In addition, for most of the analyses outlined below, the 'B' class totals from table 9 (cereals) were added to the equivalent 'B' class totals in table 10.

Table 11

In addition to their classification in the A2 to A6 classes, non-segetal species identified in the site remains were also classified by their probable source habitat as described above (6.1. step 4). The amalgamation of their scores indicated in table 11 is hopefully self explanatory.

TABLE 10. SCORE TOTALS OF WILD AND SEGETAL SPECIES FROM CEFN GRAEANOG: AMALGAMATIONS BY HUMAN ACTIVITY ASSOCIATIONS (i.e. BY THE A, B AND C CLASSIFICATIONS OF TABLE 3) : LAYOUT OF SCORE TOTALS SHEET FOR A SINGLE SAMPLE

As before, the only species used here to contribute to class totals were those for which only one of the alternative classifications was probable within each of the systems of classification (i.e. within any one of the columns A, B and C in table 3).
Within any one sample, in producing grand totals for each of the 'B' classes the relevant 'B' totals from the cereals in table 9 are generally added to the corresponding totals in this table. Class 'A1*' comprises species of probable segetal status but of uncertain classification in the 'B' and 'C' systems. The A1* total is added to the 'A' class grand total as indicated. To save space, Latin names have been abbreviated.

	CLASS A1																			A1*		A2		A3		A4	A5	A6
	B1				B2		B3								B5				B6									
	C2	nos of items	C3	nos of items			C1	no.	C2	no.	C3	no.	C4	no.	C1	C2	C3	C4										
	Avena fatua (pedicil tips) Avena sp. (pedicil tips)	xx xx	Papaver spp. (capsule fragments)	xx	Anthemis cotula (capitulae)	xx	Polygonum convolvul.	xx	Avena fatua (cpts.67-70) Rumex congl./sang./acet. Agropyron sp.	xx xx xx	Ranunc.bulb. Papaver sp. Brassica sp. Spergula ar. Chenop.album. C. murale Chenop. ind. Atriplex sp. Vicia/Lathy. Trif.med./pratense Merc.annuus Polyg.pers. P.lapathif. Veronic.arv. Galeop.seg./angust. G.tetrahit Galeop.ind. Anth.cotula (seeds) Chrysan.seg. Vulpia sp. Anisantha sp.	xx xx xx xx xx ' ' ' ' ' ' ' ' ' ' ' ' ' xx xx xx	Stell.media Scleran.per. Trifol.rep./hybridum T. arvense Aphanes mic. Polyg.avic. Anagallis sp. Prunel.vulg. Poa annua Aira sp.	xx xx xx xx xx xx xx xx xx xx	(no unequivocal examples recovered from Cefn Graeanog)					Glechom.hed. Plantag.lan. Galium.ulig. G. aparine Senecio vul. Lotus pedun./cornic. Euphorbia sp	xx xx xx xx xx xx xx	Ulex sp. Ulex/Genista Calluna vulg. - seeds - flowers - shoot tips Erica tetra. -flowers -shoot tips Erica ciner. -seeds -flowers Ericaceae indet. Pteridium -mature frond frags.	xx xx xx xx xx xx xx xx xx xx xx	Fragaria vesca Rubus idae. R.fruticos. Rosa sp. (achenes) Corylus av. Empetrum nigrum Prunus spinosa Pteridium -immature (curled) frond frags.	xx xx xx xx xx xx xx xx	(no unequivocal examples recovered from Cefn Graeanog)		
'C' class sub-totals		xx		xx				xx		xx		xx		xx														
'B' class totals	B1 total				B2 total		B3 total								B5 total					A1* sub-total	xx							
'A' class grand totals	A1 GRAND TOTAL XX																					A2 TOTAL	XX	A3 TOTAL	XX			

Table 11. 'D' CLASS TOTALS OF SPECIES OF UNCERTAIN MODE OF ARRIVAL ONTO THE SITE (ie. UNCERTAIN 'A' CLASS): AMALGAMTION BY HABITAT (D) CLASSES

This table amalgamates the scores of species of similar habitat preference which are
- unlikely to have been segetals (weeds of crops) and
- for which no other unequivocal 'A' system classification was possible.

Note: The habitat (D) classes used here are outlined in 6.1, st4. On account of the composition of plant communities in the area of the site today, it seemed pointless to assign species to classes D2 or D3 separately. These two classes were therefore amalgamated.

The habitat classes in which each species was likely to have been growing in the vicinity of the site of Cefn Graeanog during its original occupation

D1 weeds of waste land	nos. present	D2 & D3 pasture & woodland spp	nos. present	D4 marsh & bog spp.	nos. present
Urtica dioica	xx	Ajuga sp.	xx	Ranunculus flammula	xx
Ballota nigra	xx	Campanula sp.	xx	Caltha palustris	xx
		Ruscus type	xx	Montia fontana	xx
		Endymion non-scriptus	xx	Polygonum hydropiper	xx
		Luzula sp.	xx	P. minus	xx
				P. mite	
				Salix caprea type	
				S. alba type	
				Veronica scutellata type	
				Potomogeton sp.	
				Narthecium ossifragrum	
				Eriophorum angustifolium	
				Schoenoplectus sp.	
				Eleocharis palustris or uniglumis	
				Several Carex spp.	xx
				Molinia coerulea	xx
Class totals (for the one sample)	XXX		XXXX		XXX

6.3 DELETIONS

At Cefn Graeanog, deletions of taxa from further analysis occurred at two levels:

a) Deletion of individual species:
None of the species (and cereal components) of equivocal classification in systems A to D could be used in producing class totals. They were therefore eliminated from subsequent analysis. (This procedure was explained in greater detail in section 6.1. above). On this basis, 40 species (out of a total of 192 non-cereal taxa) had to be eliminated from all further analysis, and a further 32 could be used only in habitat analysis (via the 'D' classes).

b) Deletion of whole classes:
Any classes within the A to D systems which proved to be present in too few of our samples of charred remains were also eliminated from further analysis. Glynis Jones (following paper) has suggested a figure of 10% of samples as a convenient frequency below which taxa (or cereal components) should perhaps be eliminated during the early stages of analysis. This seems a convenient sort of figure. In the system outlined here, however, this 'cut-off' point of 10% is applied to **classes** rather than individual taxa. Here, then, the taxa are first grouped into classes (as described in section 6.1. above), and the equivalent classes for cereals (table 9) and non-cereals (table 10)

are then combined. And only if these classes are represented in too few samples, are they then deleted. At Cefn Graeanog there were just two classes which had to be deleted on this basis: A1/B1/C3, and A1/B2/C3 or 4. Several other classes were not represented anyway, e.g. A1/B1/C1 C3 & 4, A1/B2/C1 and 2, A1/B5/C1-4, etc. In general it was clear that classes have a far greater chance of being represented in >10% samples than have individual taxa. Thus, at Cefn Graeanog, 134 of the total of 184 non-cereal taxa, considered individually, were present in less than 10% of samples and might be considered worthy only of elimination. In contrast, the elimination of the two 'failed' classes resulted in the loss of only four taxa. The nett effect of eliminating classes rather than individual taxa was therefore to save a lot of potentially valuable information that would otherwise have been eliminated at the outset of analysis.

Despite their elimination from subsequent steps of the analyses, scores of the taxa in the deleted classes can nevertheless be traced in the 'primary score sheets' (see figs. 5 and 6). The importance of this fact is that some taxa were used as indicator species in other studies undertaken at the site. Records of their occurrence therefore had to be kept available.

7 RATIOS TO REPLACE CLASS TOTALS BASED ON ABSOLUTE FREQUENCIES

Absolute frequencies of occurrence of charred remains (e.g. in the form of class totals) provide a somewhat hazardous basis for comparison of different samples. Large numbers of chance factors are involved in any one group of plant products being first preserved by charring, then surviving in archaeological deposits and finally being successfully recovered. Any comparisons of contents of different samples must therefore eliminate (or make allowance for) the effect of these vagaries of preservation, deposition and recovery.

The most obvious solution to this problem is to convert all class totals to percentages. (Scores of individual taxa could obviously be converted in the same way, if they were being used). However, percentages have a diluting effect in that the frequency of any one item is expressed only in a state relative to all the others combined. Quantitative relationships between, say, key pairs of taxa or classes can consequently become obscured.

Ratios between pairs of taxa or class totals offer a convenient means of overcoming this problem. They can furthermore be formulated specifically to address key questions relating to site economy and to human activities concerned with the manipulation of plant resources.

When small numbers of samples are involved, calculation of ratios is often unnecessary in that similarities between the composition of the samples and the composition of equivalent present-day products is generally apparent from direct comparisons of class totals. When large numbers of samples have to be analysed, however, the composition of each sample has to be compared not only with modern equivalents, but also with each of the other samples - if only to ensure internal consistency of interpretation. Adequate appraisal of similairites 'by eye' then becomes impossible, especially when the composition of each sample is to be defined in terms of a large number of different variables (ratios): only a computer can simultaneously compare and correlate so many different pieces of information. However, to be computer-processed the variables must be expressed in metrical form, in this case - as ratios.

7.1 EXAMPLES OF RATIOS used in interpreting the composition of charred remains in terms of past agrarian practice.

The selection and use of ratios is best illustrated by a) posing a few questions relating to past agrarian practice at an archaeological site, and b) exploring the ways in which these questions can be answered by using ratios of class totals. In each of the examples which follow, ratios are represented by the same class codes as those used above, e.g. in the form B1:B3. The only exception to the use of class totals arises in cases where individual cereal components such as culm bases can, in isolation, serve as indicators of specific forms of crop processing or specific crop products. (Examples of the use of individual cereal components and individual weed species as indicators of specific processes and products were also cited in Hillman, 1981).

Example 1
Was the site an agrarian 'primary producer' settlement or merely a consumer of agrarian produce grown elsewhere? i.e. Was it a farming settlement on the one hand, or a pastoralist, craft or trading settlement on the other?

The use of plant remains to identify 'primary producers' was discussed in detail in Hillman (1981, 142-3, and more briefly in 1983). It was stressed there that the recovery of spikelets or grains from sites does not, of itself, prove that they were growing the crop locally. The closest approximation to proof of local cultivation can be provided only by the presence of products or by-products from the earliest stages of crop processing, in particular the first two products (BΣ and B1) listed in table 1. The first of these (BΣ) is the residue from whole sheaves burned either deliberately in the course of preparing fırıg or frikke (see side-loop in fig.3) or as a result of accidents in sheaf stores in those northerly areas where crops were not uncommonly bulk- stored as sheaves. The second class characteristic of primary producers is B1 - 'straw waste' (threshing-yard waste) separated in the course of raking and/or primary winnowing and coarse riddling, i.e. steps 4, 5 and 6a in fig.3).

However, both products B1 and BΣ seem rarely to be preserved on the average archaeological site, product BΣespecially. Large, unmixed samples are even rarer, and such samples are needed if charred residues of straw waste (class B1) are to be distinguished with certainty from charred remains of 'cavings' (class B2). (The principal difference lies in straw waste including awn segments, weed heads and weed seeds, though the last two components are lacking in straw waste from crops which were thoroughly weeded while growing in the field).

For use in our PCA programme the frequency of occurrence of the 'indicator' products (B1 and, less importantly, BΣ) must be expressed as a ratio, i.e. in relative terms, with a third class of remains serving as common denominator. As common denominator, this third class should clearly a) consist of material which has survived on the site as a result of the same preservation processes as B1 (it must therefore be dominated by some form of chaff), yet b) be at least as widely available in site deposits as B1, and c) its dominant (chaff) components should be entirely different from those of B1. The only class of remains which fulfills all three of these requirements is B3 - 'fine sievings' (the fifth product in table 1), and the ratio to be used is therefore B1 : B3. (BΣ : B3 can also be used, though it must be remembered that the two classes represented in this ratio share several of the same componenets. The logical substitute for this ratio is therefore (BΣ - B3) : B3.

If PCA therefore separates one or more samples in which this ratio exhibits its values in excess of trivial levels explicable by chance contamination, then the site was probably either a 'primary producer' settlement or else it bought-in straw 'waste' and/or whole sheaves. (An example of straw remains from what was probably a consumer site is described by Knörzer, 1979).

Example 2
Here, two questions have to be addressed simultaneously:
a) Which of the samples of charred remains represent prime grain products and which of them are waste fractions?
b) If any of them are waste products, which class of waste do they represent?
In addressing this pair of questions, three strategies are examined and the first two rejected.

Strategy (i): For question a), the most obvious measure of the relative abundance of waste as against prime products is the value of the following ratio -

waste class totals : prime gr.total
i.e. B1 + B2 + B3 + B5 : B6 .

Question b) could then be addressed by measuring the relative abundance of each of the waste classes against B3 (the most abundant class of waste)

i.e. B1 : B3
B2 : B3, etc.

However, this approach involves a sequence of separate analyses, and this is inappropriate for PCA. At Cefn Graeanog, therefore, this strategy was rejected.

Strategy (ii): The problem of sequential analyses is readily pre-empted by simultaneously measuring the abundance in each sample of each waste component against the prime grain (B6) class total i.e. B1 : B5
B2 : B5 etc.

But this, too, has its disadvantages.

Strategy (iii): When we first begin work on the plant remains from a new site, there is often serious doubt as to whether the 'weed' species classified as segetals really were weeds of the crop with which they were found. It is therefore desirable that we analyse the weed components (of any one class) separately from the cereal waste components of the same class, as follows:

B1 (weeds) : B6
B1 (cereals) : B6

B2 (weeds) : B6
B2 (cereals) : B6

B3 (weeds) : B6
B3 (cereals) : B6

In the course of the normal analysis, PCA will then automatically measure (across a range of different samples) the degree of correlation between the two halves (ratios) of each pair of ratios. If PCA reveals strong positive correlation, then it can generally be inferred that the weeds classified as segetals and contributing to the 'B' class ratios were, indeed, probably weeds of the crops with which they were associated and not mere ruderals which arrived in the deposit by casual means. In all such cases, the PCA print-out will list the ratios as contributing to the same 'principal components'.

By using these pairs of ratios, we therefore address not only the two questions (a and b) posed above, but also a third question, namely - were those 'weeds' classified as segetals in section 6.1, step 1, (above) really segetals?

If PCA finally separates groups of samples characterised by a narrow range of high values for just **one** of the pairs of ratios [e.g. B1(weeds): B6 and B1(cereals) : B6], then the samples concerned can be taken to represent the corresponding class of waste (e.g. B1 - 'straw waste'). But, if the same group of samples is also characterised by high values for one of the **other** pairs of ratios, [e.g. B3(weeds) : B6 and B3(cereals) : B6], then the sample represents a mixture of the two classes of waste concerned (B1 and B3). (In such a case, the PCA print-out also lists both pairs of ratios as contributing to the same 'principal component').

Example 3
If the sample represents prime grain, then was it charred in bulk storage or in the course of preparing foods such as roasted grain? I.e. was the find context used for bulk storage of agricultural produce or for the preparation of food?

Here, we are seeking to distinguish between a) grain in the semi-clean state (class B4) in which, in dry areas, it is generally put into bulk storage and b) clean grain (class B6) which has been hand-sorted ready for preparation as food. B4 grain is most likely to be charred as the result of accidents in bulk storage or the sterilization of storage pits by fire. In contrast, B6 grain is most likely to be charred in the course of grain roasting. (See figs.3 and 4).

B4 grain is readily distinguished from B6 grain by the wide range of contaminants which are normally eliminated by hand sorting in later processing stages. Once eliminated, the contaminants form 'hand-sortings' waste (class B5). Thus B4 = B5 + B6. The most characteristic component of B5 waste is the weed seeds which are the same size as the grain and which could therefore not be removed by sieving during stages 11, 12 and 13 (see table 1). Examples include **Agrostemma githago** and **Cephalaria syriaca.**

The ratio used here is therefore as follows -
grain-sized weed seeds : prime grain,
i.e. B5 (weeds) : B6.

Our studies of present-day crop products indicate that, in carefully hand-sorted grain, there is far less than one weed seed for every 20 grains, but that in semi-clean grain from bulk-storage, there is generally well **over** one weed seed to 20 grains. In the ratio B5 : B6, therefore, values substantially higher than 1 : 20 identify product B4, i.e. semi-clean grain which was probably charred in bulk storage. Values substantially **less** than 1 : 20 identify product B6, i.e. clean grain which has already been hand-sorted and which was charred probably in the course of preparing food such as roasted grain.

If, therefore, PCA separates (i.e. clusters in the scattergramme print-out) groups of samples characterised by a narrow range of B4 : B6 ratio values which fall clearly one or other side of this 1 : 20 boundary, then the identity of the crop product present in the samples is clear. Such an identification also has obvious implications for the interpretation of possible past functions of the site structures from which the samples were recovered.

However, there is a second explanation which can be offered for very low values for the B5 : B6 ratio. This alternative explanation is that the crop was thoroughly weeded while it stood in the field, with the result that conspicuous weeds such as **Agrostemma githago** and **Cephalaria syriaca** were eliminated prior to harvesting. The question of whether or not class B6 is genuinely represented can therefore be resolved only by addressing an additional question:

Example 4
Were they weeding (rogueing) their crops?

To distinguish between the two interpretations of class B6 samples raised by the preceding question (i.e. between rogueing and hand-sorting), it is possible to use the presence of spikelet forks. Forks left after sieving (a few always remain) are largely removed in the course of hand-sorting, though their presence is, of course, completely unaffected by rogueing. If, therefore, (i) the ratio of **B3(cereals) : B6** is above 1: 20 (though not high enough for any of the waste products)
and yet -
(ii) the ratio of **B5(weeds) : B6** was very low, then this would indicate that the crop had been rogued. If on the other hand, the ratio B3(cereals) : B6 and the ratio B5(weeds) : B6 were **both** low, then this would indicate that the grain sample represents grain which had already been hand-sorted by the time it was charred.

In the PCA scattergrams, samples with such distinctively different combinations of values for these ratios are normally assigned to separate groups. In interpreting the PCA print-outs, therefore, one's attention would quickly be drawn to any such graphically isolated samples, and the briefest examination of the relevant ratio values would reveal their identity as either hand sorted prime grain or semi-clean grain from a weeded crop. (Neither of these classes of product was in fact, recovered from Cefn Graeanog).

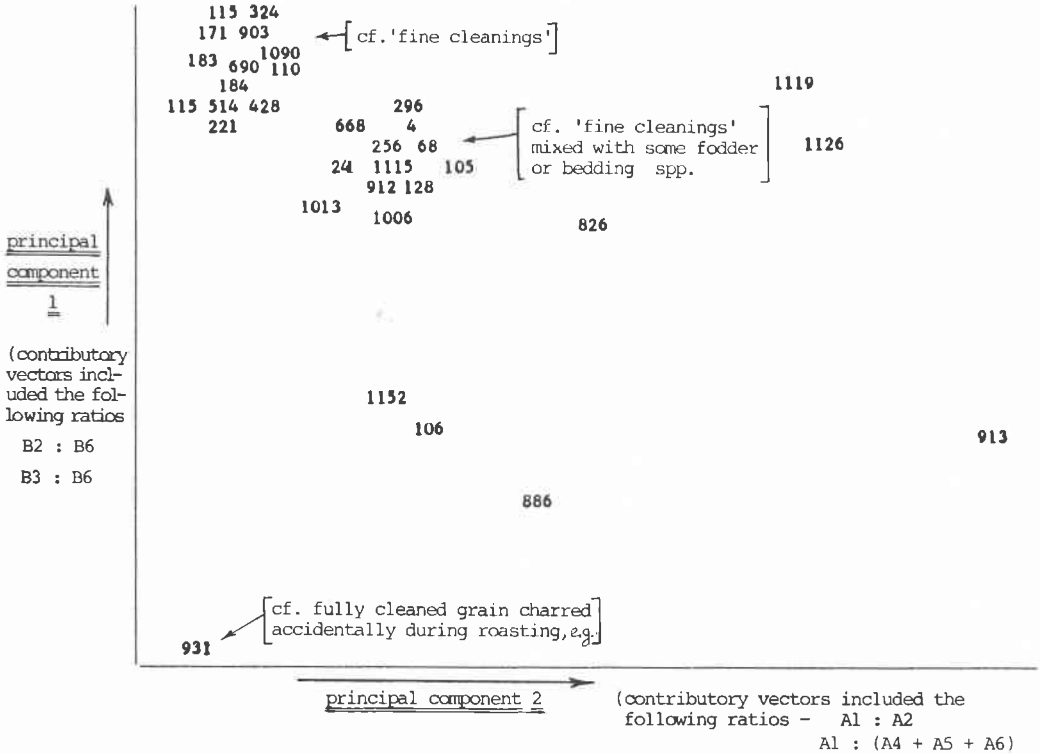
7.2 MECHANICS OF INTERPRETING RATIOS VIA PCA

It has already been stressed that the values for ratios such as those cited above can be interpeted by one of two different routes. The choice depends on the number of samples to be analysed:

a) When very few samples are involved, class totals (expressed as %s or ratios) from individual samples of plant remains can be directly compared with equivalent class totals (%s or ratios) observed in present-day plant products. On the basis of such comparisons, each sample can be separately identified in terms of the plant product type which it resembles. In some cases, the process is even simpler: the mere presence of classes such as Bl and B is sometimes sufficient to partially resolve key questions such as whether or not the site grew its own crops. (See 7.1, example 1, above).

b) Principal components analysis (PCA).
When large numbers of samples are involved, however, it is necessary to resort to computerised systems of analysis such as PCA. PCA simultaneously compares patterns of variation in the values of different ratios from each of a large number of samples and, on this basis, provides a measure of the degree of similarity between samples and a means of classifying them by groups. PCA is therefore a form of 'internal analysis' in that it defines the interrelationships of samples on the basis of similarities in their various ratio values without reference to any external system of evaluation or classification.

In most PCA systems, samples are finally plotted in the form of a scattergram according to their transformed coordinates (intercepts) on either of a pair of axes representing a pair of principal components. Several different pairs of high order principal components are used, and are automatically plotted 1 against 2, 1 against 3, 2 against 3, etc. An example of such a print-out from Cefn Graeanog is reproduced as fig.7. In such a scattergram, the distance separating any two samples is equivalent to their degree of similarity in respect of the values of all the ratios which contribute to the two principal components used in the scattergram concerned. (See fig.7 overleaf).



Each 3 or 4 digit number represents a separate sample. For some major clusters, tentative identifications are offered in terms of the product types which may be represented. These identifications are based on comparisons of the range of ratio values characterising the samples in each cluster with the equivalent values in present-day plant products.

Figure 7. EXAMPLE OF ONE OF GRAPHICAL PRINT-OUTS FROM PRINCIPAL COMPONENTS ANALYSIS OF RATIOS BETWEEN MAJOR CLASSES OF PLANT REMAINS IN SOME SAMPLES FROM THE SITE OF CEFN GRAEANOG

It is only once the internal relationships between samples have been defined as above that we can attempt to identify the resulting sample groupings in terms of the classes of plant product that they might represent:
For a start, the PCA print-out lists the ratios contributing to each principal component, so it is easy to identify those ratios which have contributed to the 2 principal components used in any one scattergramme. (See the examples given beside either axis in fig. 7). If there is a tight cluster of samples in the scattergramme, it is probable that the cluser is characterised by a narrow range of values for each of the ratios which contributed to one (or both) of the principal components concerned. And if the same samples are also assigned to clusters in scattergrams which use different pairs of principal components, then this indicates that the sample group is characterised by a narrow range of values of yet further ratios.

The values of each of the separate ratios which characterise such a cluster of samples are then traced. (For convenience, they are generally reproduced at the top of the PCA print-out). They can then be compared with the range of values for the same ratios in present-day crop products. On this basis, it is generally possible to identify each major group of samples in terms of specific classes of crop product. As with small assemblages of samples, therefore, final identification again involves direct comparison of ancient and modern equivalents; PCA is used merely to measure correlation between variations in all the different ratio values yielded by the samples and, on this basis, to indicate the closeness of relationships between these samples. In essence, then, PCA is used primarily to provide a means of identifying groups of samples which are internally consistent in their values for the widest possible range of ratios. (Such sample groups could never be identified 'by eye'). It is the ratio values characterising these **groups** of samples which are then compared, group by group, with equivalent ratios in modern products and which provide the basis for identifying each group in terms of the plant product(s) which it might represent.

At Cefn Graeanog, the PCA-generated scattergrams revealed a number of sample groups which could tentatively be identified as specific crop products. The groups which were selected fulfilled two criteria: a) Most of their component samples were densely clustered and fairly well separated from other samples in the scattergrams. b) The range of values for each of the ratios contributing to either or both principal components used in any one scattergram corresponded closely with the range of values of equivalent ratios in present-day products. In most cases, the differences in the ratio values characterising different groups were so great that the groups could be identified as particular crop products by even the most cursory comparison with even the coarsest of our qualitative assessments of the ratios observed in present-day products.

As regards criterion a) (above), the significance of the apparent distinctness of different groups in a scattergramme should ideally be tested in a more repeatable (and statisticaly more acceptable) manner using devices such as the additional cluster analyses applied to this end by Glynis Jones (see following paper).

Reduction of batch size

At Cefn Graeanog, some of our initial PCA-generated scattergrams presented an additional problem, namely that the majority of the samples were clustered in a single group. It became apparent that this was often an artifact resulting from one or two samples diverging so far from all the others that, to fit the complete spread of samples onto standard-sized computer paper, the computer had to reduce the distance between intercepts, i.e. it had to squeeze all the other samples closer together.

To test the possibility that there were distinct sub-groups (representing different plant products) within such major clusters, the samples were subjected to PCA in small batches. Three types of small sample-batches were used:

(i) We firstly took the major clusters of samples from earlier scattergrams. Analysed separately, they could now be spread over the entire scattergramme and any sub-clusters recognised more easily.

(ii) We next analysed batches of samples derived from single site structures such as huts. The samples in any one such batch generally came from a wide variety of contexts and features within the single structure concerned.

(iii) We lastly analysed samples derived from single classes of context. (Any single batch generally represented a number of different site structures). Thus all hearth samples were analysed in a single batch, similarly all midden samples, all floor samples, drain samples, etc. The major divisions between sub-groups appeared to correspond to differences in phase (period of occupation) of the source deposits. As suggested elsewhere, therefore, analyses within single context types can provide a relatively acceptable basis for site phasing whether based on charred plant remains or any other class of find.

7.3 CAUTIONARY NOTE on the use in PCA of the sort of ratios cited above.

Several of the ratios cited in the preceding sections (e.g. in 7.1) are not independent variables. The most obvious cases are the pairs of ratios used in example 2. Certain other variables which were initially assumed to be independent, often prove to be **inter**dependent in reality. That the use of these interdependent variables is unavoidable is hopefully apparent from example 2 in section 7.1, above.

In PCA, interdependent variables are automatically recognised by the programme as exhibiting correlated patterns of variation, and their variation is therefore incorporated within (i.e.

contributes to) the same principal component(s). As a result of this, the principal component(s) involved will be assumed to account for a greater percentage of total variation in sample composition than is in fact the case. This, in turn, results in these same principal components being ranked too high in the series. In using the PCA results, therefore, it is especially important to make use of principal components ranked lower down the series (e.g. p.c^{s}. 5 and 6) as they probably account for more of the variation than is formally attributed to them in the PCA print-out.

7.4 ANALYSIS OF SPATIAL RELATIONSHIPS

Most of the sample groups were identified in terms of particular classes of product (or mixtures of products) as outlined above in section 7.2. Examination of the on-site distribution of the source deposits of samples representing any one of these product types indicated that the distribution of certain products was correlated with the distribution of particular types of site context. On this basis, it was possible to identify some of the past functions of these archaeological contexts in terms of human activities concerned with specific manipulations of wild or cultivated plant products. (Examples will be presented in Hillman, forthcoming, b).

More sophisticated forms of spatial analysis of patterns of variation in sample composition were also applied at Cefn Graeanog - with the help of the pedologist John Conway. These analyses involved 'grid' programmes and 'trend surface analysis' (see Conway, 1982). Both methods required samples to have been taken at regular horizontal intervals and were consequently applied only to relatively featureless hut floors which had been sampled in metre squares. Examples of some of the results of these analyses will be presented in the full report on the site (Hillman forthcoming). Space does not allow further discussion of analysis of horizontal variation in this paper.

7.5 ANALYSIS OF TEMPORAL CHANGE

Once all components of variation **within** each phase of occupation have been accounted for, PCA can be applied to analysing major differences **between** phases in respect of differences in ratio values and thence in the crop processing and other activities which differences in ratio values represent. However, differences between phases of occupation can be convincingly demonstrated only when charred remains have been recovered from an equivalent range of context types in each phase. It is for this reason that at Cefn Graeanog, the plant-based phasing of deposits was controlled by reference to the grouping of samples in PCA-generated scattergrammes for **single classes of context.** (See end of section 7.2., above). The dangers of failing to allow for horizontal variation when interpreting apparent **vertical** (i.e.temporal) changes were convincingly demonstrated by Robin Dennell (1972) with regard to the interpretation of the charred remains from Ali Kosh. One could go further : in view of (i) seasonal variations in the pattern of deposition of different plant remains in any one context of a settlement, and (ii) the wide range of chance factors involved in any one cache of material being preserved by charring, we can claim to have fully accounted for all components of horizontal variation only when large numbers of replicate samples have been taken from several examples of each class of context within any one phase.

POSTSCRIPT

It was mentioned above (section 7.2) that, at Cefn Graeanog, the differences between the ratio values of different sample groups were generally so great that comparisons with even the coarsest qualitative assessments of equivalent ratios in present-day products was sufficient to allow the samples to be identified in terms of present-day plant product types. Despite this, however, precise measurements of the relevant ratios in present-day products are clearly desirable. Shortage of time has for some years prevented the completion of this quantitative side of the work on our Turkish models, although its completion is planned for the very near future. In the meantime, Glynis Jones has now produced many of the required measurements in her very impressive studies of the composition of crop products on Amorgos in the Aegean (see following paper). The close correlation (so far) of the results of both sets of ethnographic studies is reassuring, though not unexpected in view of the limited range of efficient methods for undertaking most jobs in traditional farming. However, it is to be hoped that others, too, will feel prompted to undertake similar studies in other areas where archaic forms of agriculture still survive. In the few such areas which still survive it will soon be too late.

CONCLUSIONS

Every major step of crop husbandry and grain processing has a consistent and readily discernable effect on the composition of crop products and by-products. These effects have been studied in archaic agrarian systems still surviving in parts of Turkey and can be summarised in the form of 'cause-and-effect' models. Patterns of variation in the composition of remains of equivalent crops recovered from archaelogical sites are found to closely resemble those presented in the models. The use of these models to interpret the composition of individual samples of this type in terms of ancient agrarian practice is therefore straightforward. However, when large numbers of samples are involved, a preliminary series of analytic steps is necessary to classify and group the samples in respect of each of the different variables. It is then these **groups** of samples which, by comparison with modern equivalents, are identified in terms of crop product types.

Analysis of the horizontal distribution of these samples and/or sample groups with respect to excavated structures then allows

a) definition of the distribution of the various crop processing activities which these samples represent,

b) identification of some, at least, of the past functions of the archaeological structures concerned.

Having accounted for the major components of horizontal variation, patterns of vertical variation in sample composition provide a basis for site phasing.

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