Deadstock and Livestock

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This paper sets out to explore three major hypotheses within the broad theme of prehistoric agriculture. The recherché title of 'Deadstock and Livestock' is intended to imply the balance between archaeological data and present day empirical research, between the inanimate and animate, and to focus attention upon anomalies which have arisen primarily because the balance has not been fully observed, tested or even recognised. The hypotheses themselves are drawn from current research programmes in train at the Butser Ancient Farm Research Project in Hampshire. Details of this project, its purpose and methodology have been published elsewhere (Reynolds 1978, 1979), but in general terms, it is a unique outdoor laboratory devoted primarily to research into prehistoric archaeology and agriculture. The objectives of the research programmes are to invalidate or confirm by empirical testing, the theories and hypotheses raised from excavated evidence. The main emphasis is firmly placed upon the Iron Age period for climatic reasons discussed below, although investigations into other periods are occasionally carried out (Reynolds 1978, Reynolds and Langley 1980). Of considerable importance is the need to stress that the experiments carried out at the farm and severally reported below are designed to test only those areas that can be subjected to testing within a scientific framework. Similarly it must be emphasised that there is no attempt whatsoever to recreate an Iron Age way of life in the sense of the popular conception of re-enactment. Indeed, the major thrust of all the research programmes is to deny as far as possible the inherently variable human factor since the data, if they are to have any validity whatsoever, must be repeatable and not unique. Consequently, those experiments which depend upon a developed skill are reported without analyses of time and effort expenditure. Human performance is the reflection of contemporary knowledge and skill and is, therefore, impossible to replicate meaningfully by those of succeeding generations. An expert, burdened by his own knowledge and developed skill, will apply techniques which were probably previously unknown; an amateur, fired only by enthusiasm, denies the skill and knowledge of the past human agency. In effect, empirical tests which seek to impose limitations of time taken upon achievements are virtually impossible to validate and are of very doubtful value. This insistence upon basic objectivity may initially seem to be a rather sterile approach but the results achieved to date from the research programmes, especially the crop yield trials, are such that without objectivity of this nature their credibility would be in question. In this sense, therefore, the Ancient Farm is a laboratory from which will emerge the boundaries of probability rather than an historically true (if such terms do not themselves present a paradox) and proved record.

The ultimate intention, of course, is to be able, in the future, to construct from all the data achieved over at least two decades, all the interactive elements of an agricultural cycle and thus to provide a valid and comprehensible basis for a deeper understanding of the prehistoric economy. It is integral to the overall intention that all of the widely divergent bio□climatic zones as utilised in prehistory should be subjected to the same developed approach as that now in train. At present, the *caveat* which must preface any data provided by the Ancient Farm, is that those data are relevant to the chalk lands and adjacent soils of central southern England unless otherwise specified.

The three hypotheses outlined below are selected to represent three major elements of agricultural practice as represented by the archaeological evidence. The first considers the problems of cultivation in the sense of ploughing and seed bed preparation. The second offers a selection of results from the crop yield trials carried out at the Ancient Farm, and the third examines the possibility that the archaeological source evidence for prehistoric crops, the carbonised seed, is not necessarily representative of the harvested cereal at all. Within the confines of this paper it is impossible to present overall surveys of the basic range of data upon which the experiments are mounted and consequently those quoted are drawn out only as examples.

ARD MARKS AND ARDS

The primary sources of evidence for cultivation can broadly be placed in four categories. These comprise the marks or scores revealed by excavation and reputed to have been made by prehistoric ards, actual remains of ards and parts of ards, representation of ards and agricultural scenes in rock carvings, and 'Celtic' or more sensibly, ancient fields.

Ard marks have been identified on a large number of widely divergent sites both in the United Kingdom and Europe. That they are prehistoric marks is simply attested by the superimposed layers of identifiable date or, alternatively, their association within a site. Generally, they comprise interrupted scores in the subsoil, occasionally unidirectional, occasionally set at right angles to each other and, more infrequently, one or more sets diagonally posed to others. At the outset, it is quite remarkable that such marks have survived at all if they form part of a regular agricultural activity, in that the repeated cultivation of a field with a standard plough would lead to a thorough stirring up of the soil to a consistent depth. The assumption here is simply that a 'standard plough' would have been used. Ard marks have been identified as early as the Neolithic, for example, at the South Street Long Barrow, Avebury, where cross ploughing had apparently taken place prior to the creation of the barrow (Ashbee 1979). An early survey of cross plough marks identified to the Prehistoric and Roman periods has been published (Fowler and Evans 1967). Subsequent to this early work, ard marks have been identified not only on the chalk and sand subsoils but over the full range of soil types including the heavy clays, for example, in Northumberland (Gillam et al. 1973) and again near Bristol on the rheatic clay (Everton and Fowler in Bowen and Fowler 1978). The assumption throughout has been that these marks or scores were the product of a prehistoric type ard, the prime evidence for which has come from the peat bogs in Denmark.

There are two fundamental surveys of the prehistoric ard types, the first by Leser (1931) and the second that of Glob (1951). The latter has played a most significant role in studies relating to ard marks and ards and has been the inspiration of several sets of empirical trials to examine the different types of ards (Aberg and Bowen 1960, Hansen 1969, Reynolds 1967,Reynolds forthcoming 1981). In terms of their production of ard marks similar to the prehistoric examples, only Hansen has partially demonstrated that such an ard, in this case the Hendriksmose ard, could create such marks in sandy soils. His experiments, however, raised considerable doubts in that the ard could not cope with a root bonded topsoil and would only create scores in the subsoil when a proportion of the topsoil had been removed. Even then the scores were hardly comparable to those archaeologically recovered in the same region

Recent work at the Ancient Farm has concentrated upon the Donneruplund ard (Glob 1951 and Plate 1) which is perhaps the best representative of the class known as beam ards. In contrast to the problems of traction experienced in the earlier experimental works referred to above, the plough team, a pair of Dexter cattle, the nearest modern equivalent to the Celtic shorthorn (*Bos taurus*), has been fully trained over a long period. The choice of the Donneruplund ard as a type was influenced by the discovery in Scotland of a similar beam in Loch Maben (Fenton 1968) and under-share in the Milton Loch Crannog (Piggott 1952-53). It shares the characteristics of the Hendriksmose/Dostrup ard types while differing in specific detail. The results from the experimental work on two sites, the Ancient Farm itself where the soil, a friable redzina averaging c. 0.10 m thick directly on middle chalk, and the Demonstration Area of the Ancient Farm, comprising a hill wash soil c. 0.30 m deep over chalk, indicates that such an ard, while admirable in producing a tilth suitable for planting crops does not create any kind of mark in the subsoil. In the former case, it simply rips up the surface of the chalk rock already subjected to permafrost action and leaves no discernible trace of its passage. In the latter, since its consistent penetration at maximum efficiency is only c. 0.15 m □ 0.20 m, it does not penetrate deeply enough to leave any abiding trace. In fact it is virtually impossible, short of breakage of the main beam, for the foreshare to penetrate beyond 0.25 m. The design of the ard is such that the angle of foreshare and undershare to beam is absolutely critical. If the angle is too deep the ard locks forward, forcing the yoke downwards and halting the cattle, too shallow and the share skips ineffectively over the surface.

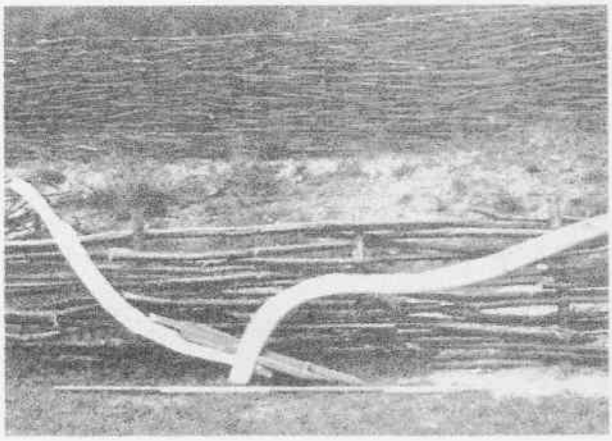

Plate 1. Replica of Donnerupland ard.

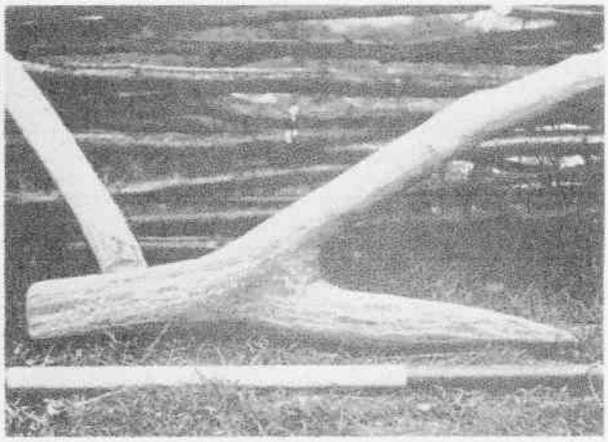

Plate 2. Replica of Hvorslev ard

Further experimentation with a crook ard of the Hvorslev type (Glob 1951) yielded similar results (plate 2). This, perhaps the simplest of the ard types and arguably presaged by the mattock hoe/digging stick or even the rope traction spade ard (Steensberg 1973) is considerably less effective than the Donneruplund ard. Although radiocarbon dating places it earlier than the beam ards, allowing some substantiation for a developmental theory to be applied to ard types, it is so ineffective by comparison that an alternative view could be offered. Also both beam and crook ards are represented upon rock carvings of presumed contemporaneity. The function of the ard, of whatever type, is to undercut the soil with the foreshare and to cause it to flow around the foot of the beam. The beam-type ards are fitted with undershares, which significantly increase the width of the foot of the beam and consequently increase the disturbance inherent in the soil flow. The main purpose of the foreshare, apart from initial penetration, is to hold the foot of the ard in a horizontal attitude just beneath the soil surface. In the experiments with the Hvorslev□type ard, it was discovered that although its functioning, as with the Donneruplund ard, depended upon critical angles, the furrow it produced was only slightly wider than the beam foot and the soil disturbance was minimal in comparison. In the production of a tilth, it was signally inferior to either mattock hoes or the beam ard. The alternative view, therefore, suggests that the crook ard is not necessarily designed to create a tilth but rather has the specific function of creating a seed drill. This view is particularly supported by the rock carvings referred to as the Litlesby Ard (Glob 1951).

Since the ard mark as such is regarded as indicative of agricultural practice, it is vitally important that an explanation for its production be proffered. There are, therefore, two basic questions involved. First, the fact that ard marks survive at all causes concern in that repeated ploughing would ultimately be self-cancelling, the end product being a totally and consistently disturbed soil horizon created by the same implement within its particular depth capacity. However, in the majority of cases, the marks, once recognised, are quite clear. In the case of a set of unidirectional marks one could quite properly argue that such a set of marks was the result of the last cultivation pass, although this is rather against the self□cancelling argument being within reach of the standard implement. Yet when there are multidirectional sets remanant in the subsoil, while the self-cancelling argument would possibly apply to a standard ard, given the number of cultivation processes required in any one season, one must hypothesise an alternative cause. The experiments carried out with the basic ard types available for study show that they are designed to travel through the soil in the horizontal plane. The protruding share, whether it be in the form of a one□piece crook ard or a bar share of wood or metal in a composite ard, is a device to hold the ard within the body of the soil and has a maximum reach in terms of depth. The tilth is produced by the stirring inherent in the flow pattern of the soil around the heel of the ard.

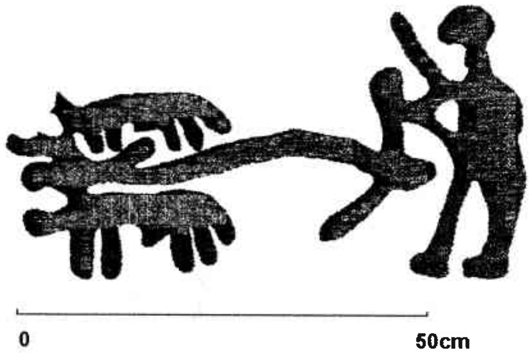

Figure 1. The Aspeberg ard (after Glob 1951).

Given that the maximum reach of the foreshare of the standard ards is shown to be no more than 0.25 m, there would seem to be omitted from the available evidence an implement capable of creating the ard marks. Similarly such an implement, by the definition of the marks themselves, could well be a specialist tool hypothesised here as a 'rip ard'. Its function would be the initial process of creating arable from scrub or woodland and again in the recovery of non-cultivated fallow into arable. The hypothesis is actually supported by the third category of basic evidence, the rock carvings, particularly the rock carving of a ploughing scene as Aspeberg, Sweden (figure I). The ard is described by Glob (1951) as of the same type as the Donneruplund/Dostrup variety. However, it would seem to differ sharply in that the stilt and share appear as a solid unit, which seems more like a hook, at a much steeper angle to the ground surface than the other representations. A similar ard appears on a rock carving from the Val Camonica in Northern Italy and in this case the scene is usually complemented by figures following on wielding mattock hoes (Anati 1961). In addition, a metal so-called ard tip recovered from an excavation of an Iron Age site at Slonk Hill near Shoreham, Sussex, is very unlike all the other metal objects identified as ard tips (Hartridge 1978). Indeed many of these metal objects are much more likely to be 'spuds', a simple metal flange mounted on a stick and used by a ploughman to clean the soil away from the ard which itself may be entirely of wood (Rees 1979). There is, in fact, very little evidence of metal sheathing for the Danish ards at all. In the Donneruplund/Dostrup types the bar share is adjustable, a facility which would be unnecessary if the share were protected, and experiments with the former variety indicate a wear pattern of c. 2.5 cm over an acre of ploughing on light soil overlying limestone (Reynolds 1967). In the case of the Slonk Hill example, the shape and wear pattern is such that it would fit onto such a hook or rip plough (Reynolds, in Hartridge 1978). Given the following description, it would seem that a metal sheath protection to this type of ard would be much more important than for the previous types.

Within the framework of the present argument it is not unreasonable to refer to a Spanish ard called 'el cambelo', in use today in the mountain region of Lugo province. This ard comprises a straight beam from the yoke which is attached to a curved oak bough. The tip of the oak bough is protected by a metal sheath, similar to the example from Slonk Hill referred to above. This ard, in effect a great hook, is used specifically for bringing into arable new ground or old fallow. In practice, the tip is dug into the soil and hauled forward by the oxen, commonly a pair of bulls rather than the more usual cows, until it locks under the weight of soil and roots. It is loosened, cleaned and the process is then repeated leaving interrupted tears or heavings of earth, roots and vegetation in the ground surface. Unfortunately, it was impossible to excavate the subsoil but, to all intents and purposes, it penetrated far deeper than any other simple ard, often being buried up to 0.50 m. Inevitably the tip penetrated into the subsoil and must have created a deep narrow score. In total agreement with the rock carvings in the Val Camonica valley, men armed with mattock hoes broke down the soil into a tilth.

Although it is extremely unwise to rely heavily upon ethnographic examples, in this particular case the archaeological evidence itself suggests the parallel rather than the reverse. Also if one is to employ parallels from ethnography at all, the area of example should as far as possible be of the same or similar bio-climatic zone. In this respect, the north west of Spain, especially the coastal strip and immediate hinterland, experience a very similar climate to that of southern England.

If one gathers these fragmentary pieces of evidence and allies them to the nature of plough-marks recovered from excavations, an hypothesis emerges which suggests that the ard marks were created by a rip ard rather than a regular prehistoric type ard, given that the soil overburden exceeded 0.25 m. Indeed, it has been suggested that the ard marks under the South Street Long Barrow are indicative of the creation of grassland from woodland (Evans 1972), a task completely beyond the physical capabilities of the normal ard group. Certainly the hypothesis above accounts for the depth and definition of the scores and their normally interrupted nature. In the case of unidirectional or criss-cross ard marks, one could further hypothesise that such an area was taken into arable once or twice only and thereafter stayed until abandonment as cultivated land. In the case of multidirectional ard marks the theory of regular periods of unploughed fallow could be advanced. Whatever the viability of these hypotheses, it is signal to record that a deliberate investigation by excavation of a group of ancient fields has yet to be undertaken. Certainly, it brings into question the rather facile approach of counting the number of directions of ard marks in an area and equating the result to the number of cultivations. (A detailed report of the experiments carried out at the Butser Ancient Farm with the Donneruplund Ard is to be published in the Proceedings of the Symposium of Woodworking Techniques before 1500 AD held at the National Maritime Museum, Greenwich in September 1980.)

Also inherent in this hypothesis is the consideration, hinted at above, that the development of the ard is not a simplistic one moving steadily forward from the simple to complex in terms of ard construction, with abandonment of one once superseded by another. It would seem more logical, given the functional effects of the different varieties as revealed by practical trials and from re□-appraisal of the iconography, that each had a perfectly normal and contemporary role. The conjectured rip ard is the 'sod buster', used on specific and unusual occasions and leaving specific and unusual evidence of its passage. The beam or bow ard of the Donneruplund/Dostrup type is the conventional tilling implement used to disturb the soil prior to creating a seedbed. Trials have clearly demonstrated that the furrows it creates are significantly too deep, some 0.30 m from trough to crest, for seed to be sown directly into them (Reynolds 1981 forthcoming). The final variety, the crook ard is, in practice, used for the drawing of seed drills for which it is admirably suited. It seems a more reasonable approach to allow a farmer a panoply of implements with which to respond to the challenge of agricultural tillage rather than to presume, tacitly or otherwise, a single implement to assume the full range of processes.

PARAMETERS OF CROP YIELD: SOME RESULTS FROM CROPPING TRIALS WITH THE PREHISTORIC CEREAL TYPES EMMER (*Tr. dicoccum*) AND SPELT (*Tr. spelta*).

The second hypothesis is directly involved with the first in that the preparation of the land by whatever means and however many processes are concerned with crop production. The basic economy of the prehistoric period from the Neolithic onwards was indisputably agriculture. Indeed, an alternative view of prehistory, rather than determining specific periods by the basic material employed for the manufacture of artefacts, would be to regard it as a straight development of agriculture. The increasing abundance of evidence from archaeological investigations and aerial surveys in the United Kingdom fully support the developmental principle, so much so that by the latter part of the Iron Age, broadly the centuries immediately preceding the Roman invasion of England in 43 AD, the agricultural landscape as we know it today was firmly established (see Fowler above in this publication). In fact, there is every reason to believe that even larger areas of arable were in cultivation, in that hundreds of hectares of prehistoric field systems evidenced by lynchets and trackways have been and still are under a pastoral regime. In this particular case, the land is generally of a marginal nature and was once thought to have been exploited by the prehistoric farmers because they lacked the technological ability to deal with the heavier valley soils. Aerial photography and excavation (Everton and Fowler in Bowen and Fowler 1978, Gillam, Harrison and Newman 1973) have now disproved this contention in terms of field evidence, and empirical examination of the available technology has shown it to be sufficiently advanced to cope with all subsoils including the most intractable clays (Reynolds 1980). Indeed, the present hypothesis for land use in the prehistoric period and, particularly, the Iron Age is that those areas of marginal land where prehistoric field systems survive represent the exploitation of marginal land at that time. Their survival today is directly attributable to a change of basic economy from arable to pastoral in the third and fourth centuries AD which has been sustained throughout the millennia. It is only in the last decade that many of these areas are being brought back into arable cultivation with the subsequent loss of archaeological evidence. The implication is clearly one of enormous pressure on available land for arable purposes on the one hand, on the other an extremely successful and stable agricultural economy.

The classical documentary evidence for this buoyant economy is quite unequivocal. For example, Caesar (DBG IV) refers to the export of grain and leather from Britain to the continent. In the same text, he describes the densely occupied landscape (*creberrima aedificia*) and further hints at the reason why agriculture was so much more successful here than on the continent when he describes the climate as having less severe frosts (*remissioribus frigoribus*). The Atlantic climate of this country is, indeed, dramatically different to that of the continent and to it can be attributed in part the consistently more advanced agricultural economy throughout the prehistoric and historic periods. This is especially clear in the sixteenth and nineteenth centuries AD (Whyte 1979, Fussell 1959). In any agricultural economy, the avoidance of extremes of climate bears directly upon its consistent development and success. It is, of course, the major variable in any consideration of crop husbandry.

The basic source evidence for the crops of prehistoric period comprise the carbonised seeds of cereals and other plants, seed impressions fired into pottery, and pollen grains. The pollen evidence, while of some value, has little relevance to large tracts of the countryside because of minimal preservation and (more importantly) unless actual pollen grain identification is definitely assured, confusion with other *gramineae* species may distort the overall picture.

It is against this background of the basic data that one of the major research programmes at the Butser Ancient Farm Project Trust (Reynolds 1978, 1979) is designed to assess potential yield factors of prehistoric cereal types under different treatments and cultivation techniques. As commented above, the major variable in any attempt to simulate the husbandry of the Iron Age is the climate. In this respect, it is argued that the climate of the last three centuries of the first millennium BC and the first two centuries AD are directly comparable to the present day climate (Lamb, pers. comm.). Naturally, this includes the minor variations and occasional extremes; for example, the drought of 1976 experienced within the modern weather pattern. Thus this variable can be seen as a constant to any empirical study of cereal production. The second variable is the soil itself. In this case the principal land area of the Ancient Farm is particularly suitable. It comprises a spur of middle chalk covered with a thin layer (c. 10 cm) of friable redzina, the typical soil covering the chalk lands of southern England. In addition, the land area of the farm has not been cultivated for the past two hundred years and it is doubtful whether it has ever sustained a substantial arable crop of any kind. Certainly, there are no archaeological traces of agriculture. There is, however, a prehistoric settlement of Bronze Age/Iron Age date located on the spur and abundant evidence in the immediate vicinity of prehistoric field systems and track□ways suggesting that the settlement was, in fact, a farmstead. Thus the soil type, with a consistent pH value of 7.2, is accurate and has been uncontaminated by modern farming techniques. Since the Ancient Farm began in 1972, every care has been taken to avoid any subsequent contamination from modern agrochemicals. The secondary land area of the Ancient Farm comprises the typical hillwash soil of present dry valleys in the chalklands known to have been exploited in the Iron Age. It is composed of a mixture of clay with flints, degraded chalk and redzina with a neutral pH value. For the past hundred years it has been under rough grass cover and is thus unimproved in the modern sense. It was taken under control by the Project in 1976 and the last application of nitrogen to improve the grazing was dated to 1974. Consequently the effects were neutralised by the time of its cultivation.

The varieties of cereals cultivated in the Iron Age are well attested by the analysis of carbonised seed and seed impressions recovered from a large number of excavations of Iron Age sites (Halbaek 1952). As excavation techniques have improved, especially with the introduction of fine mesh wet sieving and flotation systems, so the bulk of carbonised seed evidence has increased proportionally. There is still, however, too little evidence of find location within sites, except in exceptional circumstances, like pits, to determine processes or functions or even crop dominance with any certainty. As discussed below, it is preferable at this time simply to regard the evidence of carbonised seed only as statements of presence or absence. Any apparent significance suggested by an abundance of one plant species over another might be an effect of a subsequent process within the settlement and in response to a specific requirement, and not reflect the husbandry practice at all. Similarly, the very fact that the seed is carbonised at all suggests an unusual event or accident and, therefore, renders it as an atypical element within the artefact assemblage.

Nonetheless the dominant wheat cereals of the Iron Age and Romano-British periods were undoubtedly Emmer wheat (*Tr. dicoccum*) and Spelt wheat (*Tr. spelta*). Consequently, although other cereal types are the subject of cropping trials at the Ancient Farm, Emmer and Spelt wheats are the principal varieties. For this study, seed was provided by the Plant Breeding Institute at Cambridge from Asia Minor where it is still cultivated in the remote regions. Careful analysis of the seed proved it to be morphologically the same as the prehistoric seed and, while it can never be proved, it is not unreasonable to believe that its protein characteristics are equally exactly similar. Certainly its characteristics as a stable as opposed to a hybrid plant are beyond question. The development of these cereals is discussed elsewhere (Reynolds 1977).

The cropping trials at the Ancient Farm are both varied and complex. The constant within the trials, the weather pattern and soil structure, are subject to continuous recording and analysis with, in the case of the former, a standard meteorological station set on each site. In addition, certain fields are monitored for their microclimate. The treatments under which the crops are grown are, as far as possible, evidenced by either the archaeology or documentary references. The preparation of the fields and rendering of a tilth are always carried out by ard (see below and Reynolds 1981) or by spade and mattock hoe cultivation. Seed is always hand sown in seed drills (Reynolds 1967, 1981) and at a constant rate of 63 kilos per hectare (56 lb per acre). Concomitant arable weed growth is subjected to handweeding and hoeing. In certain trials, because large numbers of arable weeds commonly evidenced in the carbonised seed record are virtually extinct in the British countryside, arable weeds are deliberately introduced to provide specific and accurate competition. In association with the cropping trials, an extensive and complex research programme is devoted to the propagation, germinability and fruiting characteristics and conservation of a large number of arable weed species. Primary focus has been the calcicole species with a secondary focus in the last two years upon the calcifuge species. Throughout the trials, the competitive weed flora is monitored and analysed with special reference to potential function indicators (see below). Similarly, the crop in the field is monitored as to stand height and tillering and, subsequent to harvest, is further analysed for spikelet length and weight, fruiting capacity and seed: chaff ratio.

The following tables present the results of a selection of the field trials carried out at the Ancient Farm since 1972. The yield data are obtained by sampling the crop in the standard manner of selecting by random metre square avoiding a metre wide perimeter band around the crop where the 'edge effect' can distort results. The figures provided represent gross weight and are presented in kilos per hectare, cwt per acre and seed yield ratio. This last is the traditional historic system and allows direct comparison with yield figures from the records of the sixteenth century onwards.

FIELD II

Location	Ancient Farm Research Site, Little Butser
Soil types	Friable redzina av. 10 cm thick directly overlying middle chalk
pH	7.2
Sowing rate	63 kg/ha (56 lb/acre) in Autumn
Sowing system	Seed drills 0.30 m apart
Cereal varieties	Emmer (*Tr. dicoccum*) and Spelt (*Tr. spelta*)
Cultivation	Hand digging and mattock hoes

The objective of this trial is to assess the yield characteristics of the prehistoric type cereals on a typical unimproved soil of a type available in the Iron Age. The crops are grown without any periods of fallow and without any form of added nutrient of any kind. In effect, the purpose is to assess the long held and cherished theory of land exhaustion and the need to rotate arable areas. The intention is to continue cropping this field until a non□viable yield is recorded. Non□viability is determined to be a 1:1 or worse seed yield ratio. Table I gives the data yield for sector east of this particular field.

Table I. Crop yields: Field II, sector east, Butser Ancient Farm

	Triticum spelta			Triticum dicoccum		
Winter sown	Tonnes/ha	Cwt/acre	Seed:yield	Tonne/ha	Cwt/acre	Seed:yield
1973	2.4	19.0	1:38	2.8	22.8	1:46
1974	2.3	18.3	1:37	3.7	29.8	1:59
1975	1.7	13.7	1:28	1.8	14.1	1:28
1976	0.8	7.2	1:14	0.7	6.4	1:13
1977	2.3	18.4	1:37	1.2	10.0	1:20
1978	2.5	20.1	1:40	2.6	20.8	1:41
1979	0.7	6.2	1:12	0.4	3.3	1:7
1980	1.4	11.4	1:23	1.6	13.0	1:26

Discussion.

Relatively large fluctuations can be readily observed over the eight years within the table above but all these fluctuations are directly attributable to the weather patterns rather than any other single factor. For example, the exceptionally low figures for 1979 were caused by continuous heavy frosts on bare ground for six weeks when the ground surface temperature did not exceed 1°C. Similarly, the drought of 1976 took an exceedingly heavy toll. What is most significant is that the yield when expressed as seed yield ratio has never fallen below 1:7. Bearing in mind that there are no nutrient additives to this field area at all, and the cultivation practice is minimal in modern terms, this figure is the more remarkable. Given the validity of the experiments, there is an urgent need to determine why, with all the above restraints, this figure should be so much in excess of historical records where seed: yield ratios are significantly lower except in England and the Low Countries (average 1:10 increasing to 1:20). To further point the anomaly, table 2 gives the soil analysis results showing a minimal change in structure and trace element levels over a period of eight consecutive seasons.

Table 2. Soil analysis: Field II, Butser Ancient Farm.

	%organic matter	Potassium p.p.m.	Potassium index	Phosphorus p.p.m.	Phosphorus index	Copper p.p.m.
1972	24.3	234	2	16.2	3	4.14
1979	20.3	140	2	21.0	4	3.84

P.p.m. = parts per million

The levels of organic matter are high and are regarded as indicative of a long period under grass without cultivation. The normal figures for modern arable land is two to five per cent of organic matter. All other levels are regarded as adequate but on the low side. In effect, this system of cultivation is not reducing significantly the organic matter in the soil and the cereal varieties, in direct contrast to modern hybrids, do not require the same high levels of nitrogen input. The further point that must be stressed is the nature of the cereal itself. The spike is naturally significantly larger than that of the typical wheats of the historical period like Rivet wheat and indeed larger than the modern hybrids. There is no real indication, therefore, of soil exhaustion nor yet of deterioration of yield. The last season of 1980 clearly shows that the yield for both Emmer and Spelt has recovered from the disastrously low levels, in terms of the expectation engendered by previous years, of 1979. Similarly, although Spelt has been claimed to be a better winter variety than Emmer (Applebaum 1954), with the exception of one season, it is outperformed by the latter. Inevitably, within the confines of a short paper, it is quite impossible to present the total crop yield data achieved within the Ancient Farm research programmes. However, in order to provide a direct contrast to the above table, table 3 shows results drawn from Field VI, where the treatments of a hill wash soil described above is subjected to an application of manure at a rate of twenty tonnes per hectare, approximately half the recommended weight distribution of the recent past, once every three years. The first application took place in the winter of 1977 prior to spring sowing of Emmer wheat, in association with other varieties, in 1978.

Table 3. Crop yield: Field VI, Butser Ancient Farm Demonstration Area.

Year	Cereal type spring sown	Tonne/ha	Cwt/acre	Seed:yield	Treatment
1978	Emmer	4.65	37.2	1:74	Manured + 1
1978	Maris Huntsman	2.91	23.3	1:46	
1980	Emmer	3.19	25.5	1:51	Manured + 3
1980	Sicco	1.62	13.0	1:26	

That manuring took place in the Iron Age has been ably demonstrated by Bowen (1961). In this particular field, where manuring is applied in simulation of an availability of dung adequate to the area once every three years, it can be seen that the reduction in yield is quite significant but that in gross terms the returns are significantly better than those of Field II above. All the results quoted above are statements of the mean, and standard deviations are not supplied nor the gross maxima and minima. In simple terms, it allows the figures to bear comparison with results from other periods of history provided similarity of conditions *inter alia* is observed. If nothing else these figures support the contention that, given the cereal species of the Iron Age, the potential for surplus production existed to an extent well capable of sustaining the export industry reported by Strabo.

The figure in the above table referring to modern hybrid varieties point to the problems of comparison. Maris Huntsman in 1978 and Sicco in 1980 were selected as the best standard modern wheats available. Maris Huntsman was particularly disappointing, bearing in mind its distinguished role in the development of hybrid varieties, and Sicco wheat is generally regarded as one of the best of the present generation in terms of both yield and protein levels. The reasons why these cereals are outperformed seem to lie in two particulars; first, they need a high nitrogen input and, second, their response to weed infestation/competition is poor. By the same token, both the prehistoric cereal types require a much reduced nitrogen input and, once established, are well able to compete most successfully with abundant arable weed infestation. If they are grown within an agrochemical system, lodging becomes an immediate problem although the yield can be commensurate with the best modern varieties.

Comparative cropping of modern cereals in Field II, the autumn sown non□nutrified field, on the main farm site was abandoned by 1975 through purely negative returns. Not only did the cereal variety, again Maris Huntsman, fare badly in growth patterns and maturation, each year all the seed was stripped by bird attack prior to harvest. The awns and the cohesive glumes of Emmer and Spelt serve as extremely effective deterrents to such attack. Indeed, it is relatively difficult, given the basic requirements of modern hybrids, to provide comparative data which is meaningful to modern agriculturalists. While the data processing establishing the end figures as quoted are exactly those adopted by the Rothamsted Experimental Station in Harpenden, the real problem is the husbandry techniques. It is, in a sense, quite unfair to expect the modern varieties to be at all viable in such an inimical system. The results simply all point to the performance of the prehistoric types. Of most value, perhaps, is to measure performance against treatment and climate and to value the results accordingly.

In due course, the full results of the trials carried out at the Ancient Farm will become available. Reported above are but two sets of data, the first referring to a portion of one field, the second to two seasons results from one further field subjected to a totally different treatment. While it must be appreciated that these are the results from only nine years and four years respectively and that at least twenty years of data are required for clear cut validation, the trends and the problems posed by those trends are undeniable. Should the results be maintained even at the lower and less likely levels, the implications are such that subsistence is an ill-chosen adjective with which to describe the potential agricultural achievements of the Iron Age.

In concluding this second hypothesis devoted to crop yields it is worth recording that one particular species of arable weed has emerged as a potential indicator of agricultural practice. The species, Cleavers (*Galium aparine*) has successfully and quite naturally pervaded the field (II) sown in the autumn while the spring-sown field (IV), separated by only a metre□wide strip of turf, is completely innocent of this plant. Table 4 gives the results of the last two seasons survey of this particular species showing the figures from three randomly selected square metres per sector in both fields.

Table 4. Arable weed flora survey: *Galium aparine* (cleavers).

			East Sector	Central Sector	West Sector
1979	Field II	Autumn sown	136	179	85
	Field IV	Spring sown	0	0	0
1980	Field II	Autumn sown	84	109	63
	Field IV	Spring sown	0	0	0

The germination characteristics of this plant show a major peak at the end of March/beginning of April with a minor peak in late October. Normally, the spring-sown field is cultivated at this time prior to planting early in April and, consequently, should any plants be about to grow they are eradicated by the cultivation. By contrast, the autumn sown field is planted in early October and thus the plant can experience and benefit from both peaks of germination, allowing considerable numbers to escape the hoe and hand weeding which is carried out in late April and May. Its total absence from the spring sown field (further surveys substantiated the close search of the randomly selected square metres) is the most significant factor. Its presence in the carbonised seed record (Haelbeck 1952) may well, therefore, be considered as an indicator of autumn or winter planting of cereal crops.

HARVESTING: THE IMPLICATIONS OF IMPURITIES

The third hypothesis is, in fact, a direct result of the cropping trials in that the problem of harvesting was determined to simulate Iron Age practice. The result has become a challenge to the assumed traditional analysis of carbonised seed, suggesting that such seed does not necessarily represent the true harvest and consequently, with normal allowance for exceptions, is unlikely to bear evidence of post-harvesting treatments. Precise information of harvesting techniques of the Iron Age, in contrast to the Roman systems (White 1970), is difficult to isolate. We do have the comments by Strabo and Diodoros Siculus that the Celtic practice was to reap the ears or spikes of the crops. Support of these statements can be found in the ubiquitous artist's impressions of prehistoric harvesting where the so□called sickle is to be seen neatly cutting off cereal heads. Practice, however, has little in common with imaginative representation. From the observation of some eleven seasons of growing the prehistoric type cereals of Emmer and Spelt wheats, belief in the determination of the typical small 'sickle' has radically waned to the point of offering a specific alternative function: this being the splitting of hazel gads to make into thatching spars, for which the tool is admirably suited and similar in shape and weight to the traditional spar hook. There are further functions like bark stripping, leaf cutting, branch trimming which similarly can be effected with an edged tool of this design. This is not to say that they cannot be used for cutting wheat ears, but rather that they are grossly inefficient and far too slow. The problem lies in the nature of the crop itself. Accepting the classical sources as being a reasonable description of the actual harvesting technique, both at Avoncroft Museum and at the Ancient Farm all the crops have been harvested in this way. Each year replica sickles are provided for the purpose, each year they are unanimously rejected by the reapers. The answer is simply that it is much easier to reap the ears by hand picking.

It was realised from the very first season that the prehistoric cereals have two characteristics which are not ordinarily to be found in modern hybrid wheats. The first major difference lies in the disparity of stand heights achieved by the tillers of the same plant. In the case of both Emmer and Spelt wheats this disparity can be as much as a metre from the shortest to the tallest spike, while in a modern hybrid it rarely exceeds 0.40 m. The importance of this characteristic will be developed below. The second characteristic is the 'necking' of the prehistoric types. As the ears ripen so they droop gracefully downwards from the main stalk in the fashion of modern barley. The effect of this not only inhibits water retention within the spike and consequent lodging potential, this being truer of Emmer than Spelt where lodging can be a problem, but also exposes the stalk top to the elements of wind and sun. Once ripe, this section of the stalk becomes extremely brittle and is very easy indeed to break off. If allowed to reach maturity, the natural result is for the spike to break away from the stalk and seed itself. The skill of farming is, of course, to pre-empt this point by as short a time as possible.

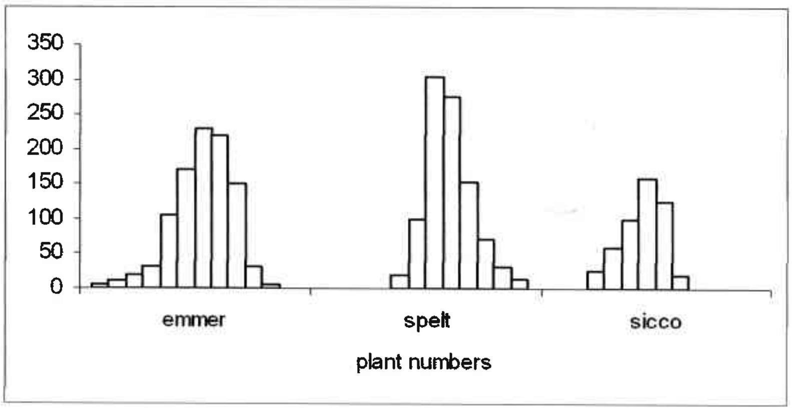

Figure 2. Relative stand heights (cm) of Emmer wheat, Spelt wheat and Sicco (modern hybrid) wheat.

Observations of this disparity of stand height have led to the direct recording of each successive crop. Annually, a thousand measurements of each crop variety and treatment are made across random transects with sample points 0.30 m apart. The results of just one year are provided to substantiate the present argument. These can be seen represented in histogram form in figure 2. To provide a direct comparison the results from a modern cereal crop grown under exactly the same conditions are included. The selection of examples is further deliberately pointed in that they are drawn from a field which has been continuously cropped for the past eight years without any added nutrient whatsoever. The farm is, of course, free from all modern herbicides, pesticides and fertilisers.

The prime archaeological data normally comprise an admixture of cereal and arable weed seeds. Throughout the cropping programme, the competitive weed flora has been most carefully monitored. In eleven seasons, all the harvests have been effectively pure with but two contaminants. By way of explanation, the harvest is taken to be the spikes that can be collected from the crop. The contaminants, in turn, are arable weeds which can be found within the gathered spikes. The harvesting process consistently follows the classical description. However, the crop itself is regularly infested with an abundant weed flora and during the months of June and July particularly is a riot of colour. The primary enemy of farmers of all periods prior to the introduction of herbicides is Charlock (*Sinapis arvensis*). It is vitally necessary during the early part of the season to hoe the crop carefully in order to keep at bay this most pernicious of competitors. In this century it was not uncommon to hear of crops being ploughed back into the soil because of Charlock infestation. Farming by definition is the provision of a preferred habitat for a specific plant. However, once the plant is established and can outgrow its competitors, there is no advantage in further hoeing and indeed there can be direct disadvantages in that too much soil disturbance in the secondary stages of crop development can damage the spreading roots of the crop itself. In addition, the weed cover actually aids moisture retention in the soil, a matter of some importance with an average depth of 0.10 m. Consequently, at harvest time, there is an abundance of other plants amongst the cereal crops. Careful note has been made of those competitors which reach the reaping height. That is, those plants which head out amongst the majority of spikes and which are likely to be collected by accident during the harvesting process. Such plants are effectively few in number and virtually all of them are sufficiently different in nature and form for avoidance to be a matter of course. The most typical on calcareous soils are the Thistle family (*Cirsium spp*), Fat Hen (*Chenopodium album*), Poppies (*Papaveraceae*), Charlock (*Sinapis arvensis*) and Hedge Mustard (*Sisymbrium officinale*). On acid soils, as well as most of the above, Red Shank (*Polygonum persicaria*) and Pale Persicaria (*Polygonum lapathifolium*) are the most common. The two contaminants referred to above are Black Bindweed (*Polygonum convolvulus*) and Sowthistle (*Sonchus arvensis*). The former simply entwines itself up the straw stalks and wraps itself inextricably about the spike. The reaper recognises its presence but can do little about it. In fact, it can be used as a food supply, the seeds being capable of reduction by milling into flour. It hardly detracts from the crop in so far as it is not a poisonous species. The latter is relatively uncommon as a contaminant and only occurs as such since its seed is wind dispersed and occasionally a seed is trapped amongst the awns of the prehistoric type cereals. It, too, is unlikely to cause any problems in subsequent utilisation of the harvest. It is rare amongst the carbonised seed record as is only to be expected from its nature and it has recently been identified from an Iron Age site along the course of the M3 motorway (P.J.Fasham, pers. comm.). Even though its presence within the harvested spikes is occasional, this is not to suggest it is rare amongst the crop. In fact, because of its normal height at fruiting being regularly in excess of one metre it appears as a dominant weed. The presence of but one seed in the carbonised record would suggest that it was similarly a dominant weed in prehistoric crops.

The purity of the harvest is the direct result of the reaping system. Since the abundant weed flora occupies the bases of the crop and, while it does not necessarily detract from its overall performance, it does mask from the view of the reapers those spikes which are in the lowest stand height range. It would be counter□productive to hunt about amongst the base of the crop to recover what amounts to less than one per cent of the total yield. Ironically, there is regularly no difference in the overall seed size of these 'lost' spikes to those of the reaped harvest. Consequently, they cannot be identified as being distinct in any specific analysis programme. Similarly the observation needs to be made that carbonisation itself does not affect seeds uniformly and thus predictive assessments of original seed size are impossible.

The argument, therefore, is now confused in that, to all intents and purposes, the norm would have been a pure harvest and yet the carbonised seed samples are normally anything but pure. Returning to the field situation, once the spikes have been harvested, there remains still a second and extremely valuable product to be collected, namely the straw. Because of its relatively low gloss factor, the straw from the prehistoric cereals is quite palatable for livestock. Similarly, it has great value as thatching material, a fact substantiated by the stand heights alone and it would have been required as bedding material for livestock and not improbably for humans. There is always the alternative that, then as now, the straw could have been burned in situ but this does not deny the need for straw within the agricultural economy and it is not unreasonable to assume that it was cut, put into sheaves and carted back into the settlement. In any event, the field area would have had to be cleared prior to its recultivation. The straw inevitably contained the mass of weed flora within its bulk. In this way, apart from the harvested cereal, the arable weeds could have found their way into the settlement. In order to quantify this exercise, each year several of the straw sheaves from the farm are analysed for the seeds they contain after a winter's storage within a stack. The results from just one example are given in table 5 . Even this analysis does not give a true reflection of the field state in that the seed release mechanisms of the different species of arable weeds are widely divergent. For example, the thistle population, since its seeds are wind dispersed, is rarely represented. Similarly the seeds of Charlock (*Sinapis arvensis*), are exploded from a pod at the slightest touch of the trigger element. In fact, just prior to harvest one can actually hear the pods exploding as the wind□blown stalks of wheat brush against the seedpods. Some simple measurements carried out at the Farm have shown that Charlock can deliver its seed up to three metres from the parent plant. Both Thistles and particularly Charlock are dominant weeds of the research crops, a fact which analysis would fail to substantiate. As has been suggested above in reference to Sowthistle (*Sonchus arvensis*), attention needs to be focused upon the characteristics of individual plant species and any analysis needs to take account of these characteristics. An aggressive weed in the field need not necessarily appear in quantity in carbonised material.

Table 5. Sheaf analysis: Field TI. Harvest 1979. Remanent seeds.

Harvest 1979. Sheaf 11, *Tr. Dicoccum*. Gross Weight 1.9 kg				
Number of straws	980	Arable weeds:	*Sinapis arvensis*	96
Complete spikes	0		*Papaver rhoeas*	192
Rachis ends	292		*Odontites verna*	380
Seed yield	66		*Galium aperine*	22
			Poa pratensis	476
			Lolium perenne	504
			Others	200

However, there is yet the problem of carbonisation, of which some account should be taken. For carbonisation to occur, a fire with a primarily anaerobic atmosphere is required. Undoubtedly some fires are the product of accident, but the following hypothesis seeks to offer a positive alternative to accident. That houses were thatched in the Iron Age is attested by the classical writers and one presumes that straw among other materials was used for this purpose. While it is readily recognised that river reed (*Phragmites*), heather (*Calluna vulgaris*) and even bracken (*Pteridium aquilinum*) could well have been used, the last being a potential explanation of bracken spores identified on calcareous sites, straw undoubtedly was a readily available material product of the agricultural process. The preparation of straw for thatching requires one most critical operation, it must be cleaned of all other materials including its own leaves, any pithy plant stems, all seeds and especially cereal seeds. The reasons are straightforward. Pithy material rots and by so doing would decrease the bulk and cause the ties to loosen. Any seed material attracts the attention of rodents who, in turn, may well eat the bundle ties in order to reach the food supplies. Traditionally, straw cleaning and the preparation of bundles of yealms which form the thatch require the wetting down of the straw to facilitate the drawing of the straw stalks. The possible implications of the process for the disposition of post-holes is discussed elsewhere (Reynolds 1979). The end product of this cleaning process is a pile of damp waste material comprising arable weeds, stems and seeds and waste cereal heads. It is but a small step to hypothesise the disposal of this damp rubbish with a slow-burning bonfire. Such a bonfire inevitably has within it an anaerobic atmosphere which will allow some carbonisation to take place.

The two factors which form the objective of this aspect of cereal investigation are, in effect, the result of two distinct approaches, each relying upon the documentary and archaeological evidence available to us. The first is the pure harvest, the direct result of actually growing prehistoric type cereals in ancient-sized fields and processing them accordingly. The second, the commonly found admixture of carbonised seeds is questioned as being non-representative of a harvest and an alternative hypothesis is raised. If the first, the pure harvest, is a valid hypothesis then the second is most unlikely to be representative of that harvest. Throughout it must be emphasised that one is dealing with possibilities and at best probabilities, and it would be foolish to deny other hypotheses provided that they can be similarly validated. In effect, both the above hypotheses are offshoots of the main research purpose, that being to establish probable parameters of yield for the prehistoric cereal types given different soil types, treatments and bio-climatic zones.

In conclusion, the second and third hypotheses, the heavy yield potentially experienced in the Iron Age and the argued purity of harvest, are to an extent substantiated by a machine. Both classical references by Pliny and relief sculptures at Buzenol in Luxembourg and Arlon in France and Virton in Belgium describe a reaping machine called a vallus. That it merits comment from Pliny as a peculiarity of the area and specifically non□Roman is of great importance. It has, naturally enough, received attention from a number of researchers, notably Martens (1958), Fouss (1958), Renard (1959) and de Moule and Coudart(pers. comm.). Its manufacture, apart from the iron bands around the spoked wheels, would seem to be entirely of wood. Its design and operation, clearly shown in the illustrations, is specifically for the collection of the spikes of the cereals. Trials with a reconstruction (Fouss □ personal letter to Mme J□B.Delamarre dated 17 January 1961) describe it to be extremely efficient leaving very few spikes on the ground. To date, no trials have been carried out at all with the prehistoric type cereals, which would by nature be most suitable because of the brittle characteristic. (A reconstruction and trial is scheduled for 1981 at the Butser Ancient Farm.) In the present context, the most important issue is not so much the efficiency of the machine but rather that its invention actually occurred. Developments in agriculture are traditionally in response to a specific need. A reaping machine, therefore, in a labour□intensive economy would imply surplus production potentially beyond the capabilities of the labour market.

CONCLUSION

In this paper, three hypotheses have been explored, each one of which has resulted from the empirical testing of theories raised upon the archaeological data. Throughout, the methodology has consistently sought to invalidate the hypothesis in the normal tradition of scientific enquiry. The broad results have on the one hand provided negative responses to certain accepted views, on the other have contributed substantiated hypotheses which are essentially positive. It is necessary, however, to draw attention to a major *caveat*. The results quoted here, which are statistically valid and achieved under the most rigorous conditions, are relevant to the bio□climatic and geological zone within which they were gained. Specifically, they relate to the chalk downs and valleys of Southern England. The sites are, in fact, not the best available in those areas and given more ideal locations the results could well be improved. Given the suitability of the present climate for such simulation studies, both in the United Kingdom and on the continent, it is important and urgent that similar research programmes should be mounted in different bioclimatic and geological zones. In addition, such research programmes should be designed as parallel and complementary to those described above. In the view of the writer, it is only by this particular research approach that archaeological data can be amplified towards a fuller comprehension of the complex social and commercial structure of the Iron Age period. Not only does it seek to test the basic theories upon which broad generalisations should only be raised, it focuses attention upon the anomalies of the data and indicates those areas in most need of examination. It is signal to conclude with the observation that settlement is the function of farming and not the reverse and that the greatest concentration to date has been indisputably upon settlement. Economy is directly concerned with production.

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