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# Experimental Iron Storage Pits: An Interim report

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The aim of this paper is to explain the principles of the storage of grain in underground pits and to present an interim summary of the results so far obtained from a long-term series of grain storage experiments and their implications. At the outset it must be made clear that the trends indicated by the results are, in fact, trends and that the implications presented are to be considered accordingly. A major problem that besets any experimental research programme, especially in the field of agriculture, is the need for consistent and long-term replication of specific experiments in order to gain sound and reliable data. However, it is equally important that interim results should be published both to present the problems suggested by those results and to avoid the possible duplication of work by 'ad hoc' exercises. The basic point so far appreciated is the great need to focus much more attention on the careful acquisition of the raw archaeological data from excavations in such a way that valid comparisons between feature types can be made and that subsequent experimental work can have a statistically proven basis.

An excellent survey of the documentary and archaeological evidence for pits in the Iron Age has already been published (Bowen and Wood 1968). This paper also includes a report of an exploratory experiment storing corn in underground pits.

Evidence from both excavation and field work clearly shows that the pit is the most widespread and characteristic vestige of Iron Age occupation of lowland Britain, though apparently absent on some settlement sites, and consequently represents a way of thinking current over a very large part of the country involving all the major soil types. A very large number of the pits, despite the considerable variety of shape, size and detail, were probably used for storage and most of these were probably used expressly for storing grain.

The research programme, both current and planned, is directed towards seeking answers to a sequence of questions concerning pits that are vital to our further understanding of the practice and principles of the Iron Age period. The questions can be divided into two categories, *general questions* concerning the place of the pits within the economic framework, and *specific questions* relating to the functioning of a pit under particular circumstances. In the former category, the need to obtain reliable facts and figures from experimental work with pits which can contribute toward estimations of possible arable acreage and, by extrapolation, to the even more difficult problem of population calculation is perhaps the most important. One significant question raised by the work of Bowen and Wood is the definition of the life span of a storage pit since it is a vital factor in any population computation. Since pits can be seen to occur in successive series on the majority of settlement sites, the determination of the length of time for which any pit can be used successfully for storage of grain is critical. Further to the observation above that pits occur with great frequency on Iron Age sites, the elements of the economy and ways of thought they represent need to be isolated. Similarly we need to know whether the areas devoted to pit complexes currently in use on settlement sites are reserved solely for storage purposes or if such areas can figure in the general winter economy as work areas.

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The specific questions are devoted to the micro-environment of the pit. Concerning size and shape it is necessary to determine the effect of these factors in producing the required concentration of carbon dioxide and temperature patterns in the intergranular atmosphere and to decide if the beehive shaped pit so frequently found is initially deliberate in form, or the result of erosion and cleaning and subsequently deliberate

There is a considerable body of evidence suggesting a variety of types of lining in some excavated pits which needs to be tested empirically in order to evaluate the importance of such linings and if at all possible to indicate improved methods of their detection in the field. The kind of seals or covers for pits necessary to combat weather and rodents presents another specific area of research. Rarely, large jars, comparable to the Minoan and Trojan *pithoi*, are found sunk into the ground (Partridge, pers. Comm.), some of which contain quantities of carbonised grain. What are the implications of such large storage jars, and can leather-hard but unfired *pithoi* be used as adequate storage containers?

In seeking to provide answers to the above question it is clear that the line of enquiry must run from the micro-situation to the broader context and that results of the former could well preclude any solutions of the latter. This particular sequence has been adopted throughout the rest of the paper working from the situation of the pit itself to the broader implications of the trends suggested by the results achieved to date.

The principle of grain storage in a pit is essentially quite simple. In a sealed container, grain will continue its respiration cycle using up the oxygen in the intergranular atmosphere and giving out carbon dioxide. Once the atmosphere is sufficiently anaerobic the grain reaches a state of dormancy. Provided that the anaerobic atmosphere is maintained, the moisture content remains unaltered and a consistent low temperature which inhibits microflora activity prevails, the grain will store successfully for a considerable period.

The principle of grain storage in underground pits is certainly not exclusively prehistoric nor does it belong to specifically primitive cultures. The modern method of hermetic storage of grain in above-ground silos owes much to the principles of pit storage. In the nineteenth century in France grain was successfully stored for a period of five years in hermetically sealed metal lined concrete underground silos (Mannessier 1950). A similar system of concrete storage pits designed to be impermeable to gases and water vapour is in use today in Africa and South America. In Argentina alone, storage capacity in underground silos exists for about 2,000,000 tons (Hall and Hyde 1954). However, in all the above situations the dominant factors are the impermeability of the pit lining and dryness of the grain at storage, the highest admissible level of moisture content being 13 per cent. This figure is also recommended for the grain storage fossae in Malta (Hyde and Daubney 1960), the shape of which is reminiscent of the beehive-shaped pits of the Iron Age period. Constructed by the Knights of St. John under the grand Magistracy of de Redin (1657-60), the Maltese fossae have capacities ranging from 50-500 tonnes. In contrast, the largest of the excavated single pits on Maiden Castle (Wheeler 1943) has a capacity of between four and five tonnes.

A further modern parallel can be seen in the beehive-shaped pits of the Chibi district in Rhodesia (Robinson 1963). In the same country, the grain storage pits of the Matabele tribe have a similar size range to the excavated examples of the Iron Age and the principle of sealing them with cattle dung accords well with Tacitus's description. This last point also offers an indication that an area devoted to pits does not necessarily have a single function since they are commonly positioned within the cattle compound.

From the above it is evident that the practice of underground storage of grain and other food-stuffs is widely distributed both in time and geographical context. However, the variables presented by climatic zones or employing the use of modern materials preclude any direct or accurate comparison with the procedures adopted in the temperate European zone and specifically in Britain in the Iron Age period.

It is not the object of this paper to present a survey of all excavated pits from Iron Age sites nor to select a specific area embracing one basic substrate; rather it is to acknowledge the presence of probable storage type pits on a great number of Iron Age sites encompassing the majority of soil types to be found in this country. While the size and shape of pits may vary considerably, not only from site to site, but from one pit to another within a particular site, a broad pattern for size and shape is discernible. During the excavations at Little Woodbury, Professor Bersu recognized this factor and produced a basic diagram which is applicable to the majority of pits not only on that particular site but to sites in general. Fig. 1 shows a similar diagram. Bersu's point has been taken a stage further by superimposing the three basic non-cylindrical forms into one, since in terms of grain storage efficacy they possess the same characteristics of a narrower neck and increased internal capacity. Discussion concerning the process which may have led to the non-cylindrical form appears below. At Little Woodbury, discounting all the pits less than 1 m. in depth, form A in fig. 1 with a depth range of 1 m to 2.5 m represents approximately 31 percent of pits while form B in fig. 1 represents approximately 28 percent. In general terms these percentages seem typical of a

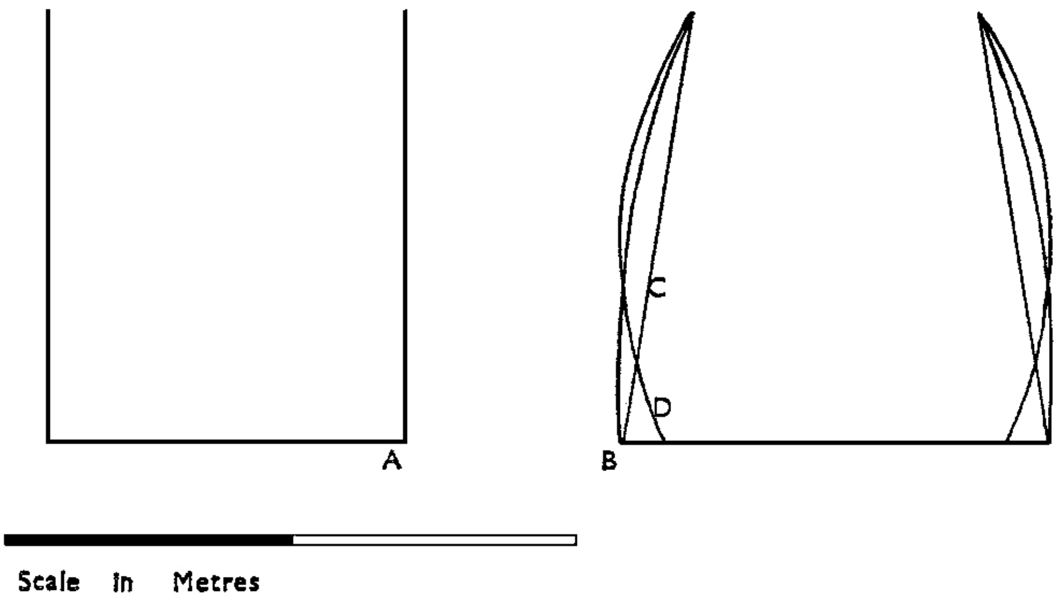


Fig. 1
Standard pit shapes

large number of sites and given the premise that their probable purpose is for grain storage the experimental programme adopted a basic constant size for cylindrical pits of 1.25 m diameter by 1.50 m in depth and for beehive-shaped pits 1 m in diameter at the neck to 1.50 m in diameter at a depth of 1.50 m. Both cylinder and beehive-shaped pits have approximately the same cubic capacity of 1.2 cu m which, expressed in terms of modern threshed barley, represents 1.12 tonnes. Since the naked and hulled two-row and six-row barleys were grown and stored in the Iron Age and since their size is very similar to the modern variety, considerations of weight to capacity and behaviour under storage conditions should be acceptable. Further work regarding emmer and spelt is being carried out at present in order to establish weight/capacity figures for different states of the seed. Since both varieties are extremely difficult to thresh a number of variables have to be considered for their storage. After harvesting the ears in the manner described by Strabo and Diodorus Siculus, several possibilities for treatment present themselves. The grain could have been stored in the ear which clearly reduces the amount that can be stored in a given capacity and also increases the intergranular atmosphere. The benefits of this practice lie in the protection afforded to the seed by the glumes and the complete recovery of the stored grain. On the other hand it is relatively easy to reduce the spikelet but extremely difficult to remove the glume. In fact the most practicable method is to break down the spikelet only and store in this way. However, these different states for both emmer and spelt will yield considerably different figures in terms of weight/capacity. Some limited but very successful experiments have been carried out storing both modern barley and emmer in the ear.

After the initial phase of experiments which concentrated on pits of average size as evidenced by Bersu's excavations at Little Woodbury, it was decided to reduce radically the experimental pit size to 0.66 m diameter by 1 m depth in order to combat the steadily increasing cost of grain, at present averaging at £40 per tonne, and more importantly to examine a multiplicity of variables simultaneously. In this way the weather conditions of any particular storage period could be regarded as a constant with regard to those particular pits being tested. Recent experiments comparing both the standard pit and the small experimental pit indicate so similar a behaviour pattern that the results of small pits have been validated. Size, therefore, is not a factor with regard to efficient storage, but larger pits could well be favoured in terms of economic usage.

The determination of constants for all the phases of the grain storage experiments has been an extremely difficult task. Initially, the prime purpose was simply to determine whether the principle of storing grain in a pit was viable. However, in view of the need for long-term acquisition of reliable results, the following constants have been in operation from the outset.

The grain used has been modern threshed barley at a standard moisture content of 16 per cent. Barley was chosen principally because of its similarity in shape and size to prehistoric barley. The moisture content, on the other hand, is significantly higher than that preferred in the systems mentioned above since in this temperate climate it is extremely difficult to harvest cereals at less than 14 per cent. The unquestioned need for grain driers in the modern farming situation is ample proof of this. Similarly 14 per cent content would be the optimum that could be hoped for in the Iron Age. A moisture content of 16 per cent seems a practical and realistic compromise.

Although every effort has been made to standardise pit shape and size in the experiments it is necessary to point out that exact dimensions are impossible to achieve in practice, especially in limestone and chalk subsoils. Both limestone and chalk crack in vertical and horizontal layers of differing thicknesses. Consequently exact depth is difficult to achieve and shaping the pit sides also present great problems. All too often the final shaping causes irregular blocks of material to fall away from the wall – a fact of life evidenced in the archaeological record where many pits have irregular wall structures and on occasion distinct rectilinear shapes. This last in chalk rock is accentuated by the polygons and fissures caused by permafrost conditions (Williams 1973) which penetrate on the vertical or near vertical plane. Oolitic limestone, on the other hand, presents the problem of natural cavities in the rock formation. One of the pits of the initial experimental phase exposed a fissure of unknown depth. Its capacity exceeded the range of a two-metre pole and in real terms was responsible for the partial failure of that particular pit.

It is worth recording that in both the above rock types the standard pit needed 25 man hours of excavation by an experienced operator. For two pits of this size, 6 and 16 man hours of excavation time were recorded by Bowen and Wood. The tool most suited for the excavation proved to be a simple hand pick which possessed all the qualities of the deer antler except that it was slightly lighter. A hand shovel was used to empty the spoil. The tool marks often observed in Iron Age pits would seem to come from the latest cleaning process and could well be made by metal or antler implements. The discovery of 'pickmarks' in excavated pits therefore is not necessarily an indication of initial manufacture but quite likely represents the effect of regular and possible annual cleaning.

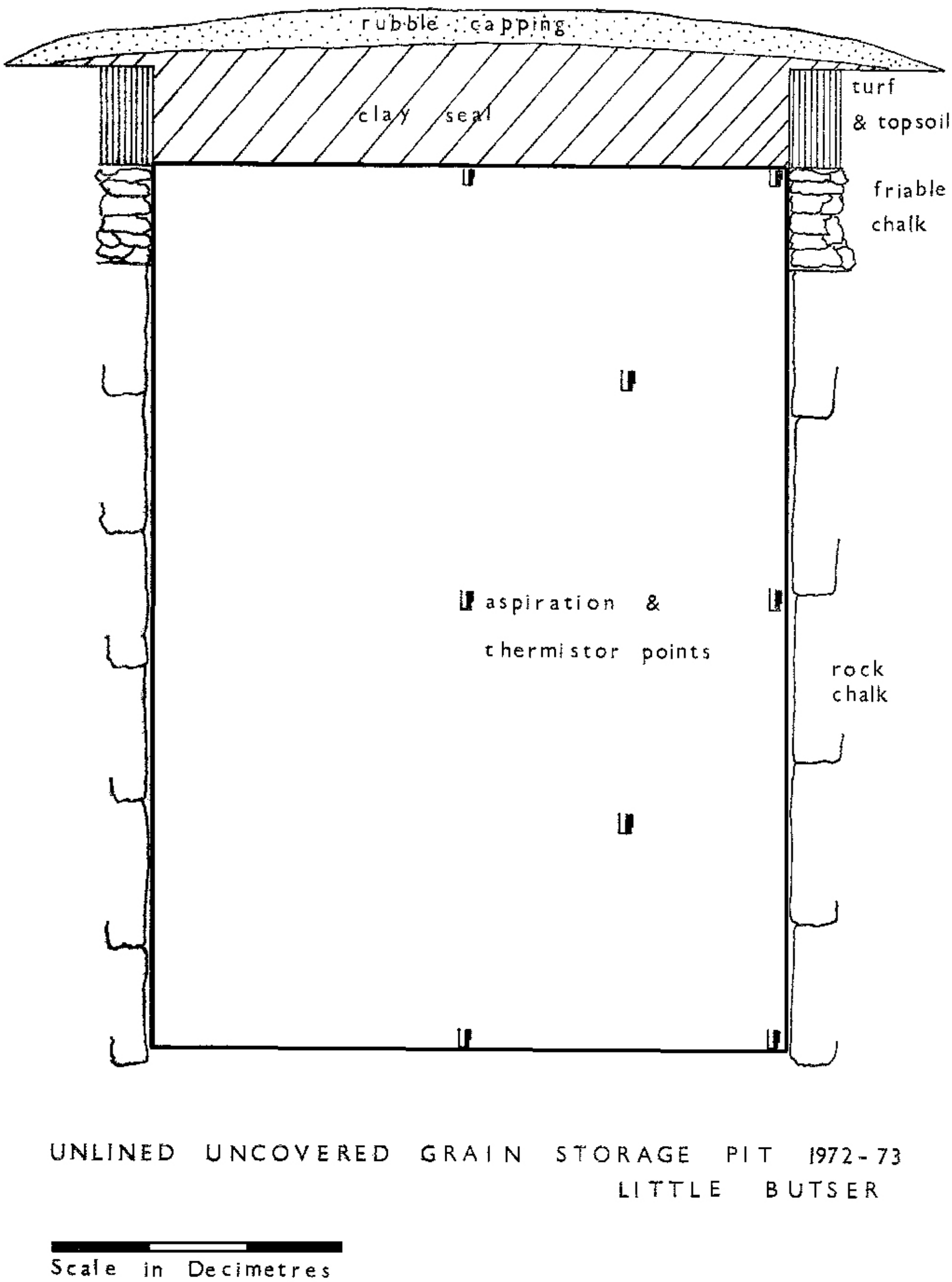


Fig. 2
A typical experimental pit

Throughout the experiments, fresh valley clay has been used as the sealing agent; for all subsoils except the chalk, blue lias clay was used and for chalk, gault clay. In the first year plywood was used to separate the clay from the grain surface; in the second year this was replaced by straw; thereafter the clay was daubed directly onto the grain surface. Also in the second year the principle of finishing the sealing process to be flush with the ground surface was adopted. The object of this has been to discover whether a pit area needs to be specifically reserved at all times or if, once the storage has been accomplished, the area can become functional for other activities. This latter case seems to have been proved beyond question. A tractor and trailer loaded with several tons of wood was driven over a number of pits without damage, and people walking over sealed pits similarly have no detrimental effect. In fact, some benefit accrues in that the process compacts the earth and clay seal. On one occasion the work area was so well trodden that a particular pit was temporarily lost. This seems adequate support for Tacitus' explanation of the underlying purpose of storage pits. However, one observation made in 1966-7 is particularly interesting in that with a light snow cover, because the internal temperature of the pits was greater than the surrounding land mass, the presence of each pit was clearly marked by a small circular area of exposed soil.

The recovery of data concerning the stored grain mass within each pit has caused considerable difficulties since any instrumentation could cause contamination of the grain or provide a weakness in the sealing process. Initially copper tubes mounted on a wooden batten were used for the collection of gas samples by aspiration, a total of 600 cc being extracted for each sample. Copper presented the least possibility of any chemical reaction while providing considerable strength. Subsequently glass tubes were employed which in turn gave way to the ubiquitous polythene. This last combines all the virtues of strength and durability, and is not chemically reactive in this context. Further it is much easier to attach a reliable seal and dispenses with the need for a supporting wooden batten. The purpose of the aspiration tubes is to extract a sample of the intergranular atmosphere to determine the percentage by volume of carbon dioxide. For this two systems have been used, back titration based on a 600 cc sample and direct absorption based on a 100 cc sample. Both systems have an accuracy to within 1 per cent but the latter has the advantage of removing a much reduced sample. After the first phase of experiments on a limestone subsoil it became possible to use bead thermistors to assess intergranular temperatures at fixed points within the pit. The bead thermistor used has an accuracy to within 1ºC. However, because of the extremely delicate nature of the bead, breakages occur, usually immediately after the pits have been sealed.

The full sequence of experiments to date can be seen in the table. It is not the object of this paper to present a detailed case history for each individual pit but rather to outline the main trends that are becoming established and to indicate the limits within which the present research programme is yielding information. The above discussion has already explained the problem of size and shape of pits and demonstrated the constants employed in the experiments. The following is a brief description of the variables examined and some direct implications. The design of a typical experimental pit can be seen in fig. 2. Each pit is committed in October and recovered in the following April. An experiment to examine the possibility of continuous storage over a longer period of time will shortly be commenced at the Butser Ancient Farm site. The prime argument for limited period storage is the considerable increase in ground temperature during the summer months to a level which would greatly increase the activity of microflora. This is especially the case since the moisture content of the grain is regularly increased during the storage from 16 per cent to 19 – 20 per cent, thus presenting ideal conditions for fungal and bacterial activity despite the anaerobic conditions.

It must also be made clear that each pit has been designed in order to succeed within the limits of the variables discussed above. Deliberate mistakes were made in the experiments at Broadchalke (Bowen and Wood 1968), with predictable results.

Success in grain storage is measured in two ways. The first test is concerned with edibility. Each pit is examined for toxic microflora. Secondly the grain is tested for its germination qualities with 50 per cent germination being regarded as a mean.

| *Subsoil Type* | *Chalk* | *Clay (Blue Lias)* | *Clay (Clay with Flints)* | *Sand and Gravel* | *Marl* | *Limestone* | | |
|---|---|---|---|---|---|---|---|---|
| Cylinder Basket Lined (standard) | | | | | | *† | | |
| Cylinder Unlined (Standard) | * | | | | | *† | | |
| Beehive Unlined (Standard) | * | | | | | | * | Threshed modern seed barley at 16% moisture content |
| Cylinder Unlined | * | * | * | * | * | | | |
| Cylinder Stonelined | | | | | * | | † | Threshed modern seed barley at 22% moisture content |
| Cylinder Clay Lined | * | | | | * | | | |
| Cylinder Basket Lined | * | | | | * | | | |
| Cylinder Algae Infested | * | | | | | | | |
| Cylinder Fired | * | * | | * | | | | |
| Beehive Unlined | * | | | | | | | |
| Cylinder Unlined within Structure | * | * | | * | * | | | |
| Cylinder Basket Lined | | | | | | * | Modern barley in the ear | |
| Cylinder Unlined | | | | | * | | Emmer wheat in the ear | |

No indication of the number of replications is given in the above table.

What has been quite remarkable is the fact that apart from three pits, all in clay subsoil and predictably doomed in that any hole dug in clay becomes a well, every pit has passed the first test and the large majority the second. In several pits in a chalk subsoil a germination level in excess of 90 per cent has been achieved. If, as has been demonstrated beyond question, grain retains a high germination potential after being stored for a six-month period, two possibilities are presented. The first and normally accepted possibility is that grain stored in a pit is specifically for consumption. However, the drawbacks presented by opening an outdoor pit during the winter period, removing a quantity of grain and then resealing the pit are quite considerable. The process has been tested empirically (Reynolds 1969). By opening the pit, the balance of carbon dioxide, moisture content and temperature is completely disrupted. On resealing, regeneration of carbon dioxide has to take place which in turn causes increased loss of grain on the periphery of the stored mass. Alternatively, a pit needs to be completely emptied and all its contents used. Both procedures would seem grossly inefficient, the first, because it disrupts the storage process and increases loss, the second because it argues an inefficient use of man time. Alternative systems of above-ground storage of consumption grain are apparent in the archaeological record. The incidence of large storage jars and certain fragments of 'daub' without wattle marks which could well be remnants of leather-hard storage jars suggest a possible process.

One season of experiments with leather-hard *pithoi* or storage jars has been completed with perfect results. Two unfired jars, each with a capacity of 80 kilograms, were filled with grain in late autumn and kept within a structure. One was sealed with moist clay with an aspiration tube previously inserted in order to collect gas samples from the centre of the jar, the other was left open at the neck and regularly checked. The aspirated gas samples showed no increase of carbon dioxide at all, indicating negative germination. In fact the leather-hard clay absorbed any excess moisture from the grain mass, providing ideal storage conditions. Archaeologically there would be no evidence for this practice except in the case of a conflagration when the resultant fired fragments of clay could easily be mistaken for daub. Recently, evidence for storage jars sunk in the ground has been forthcoming from excavations at Puckridge (Partridge, pers. Comm..)

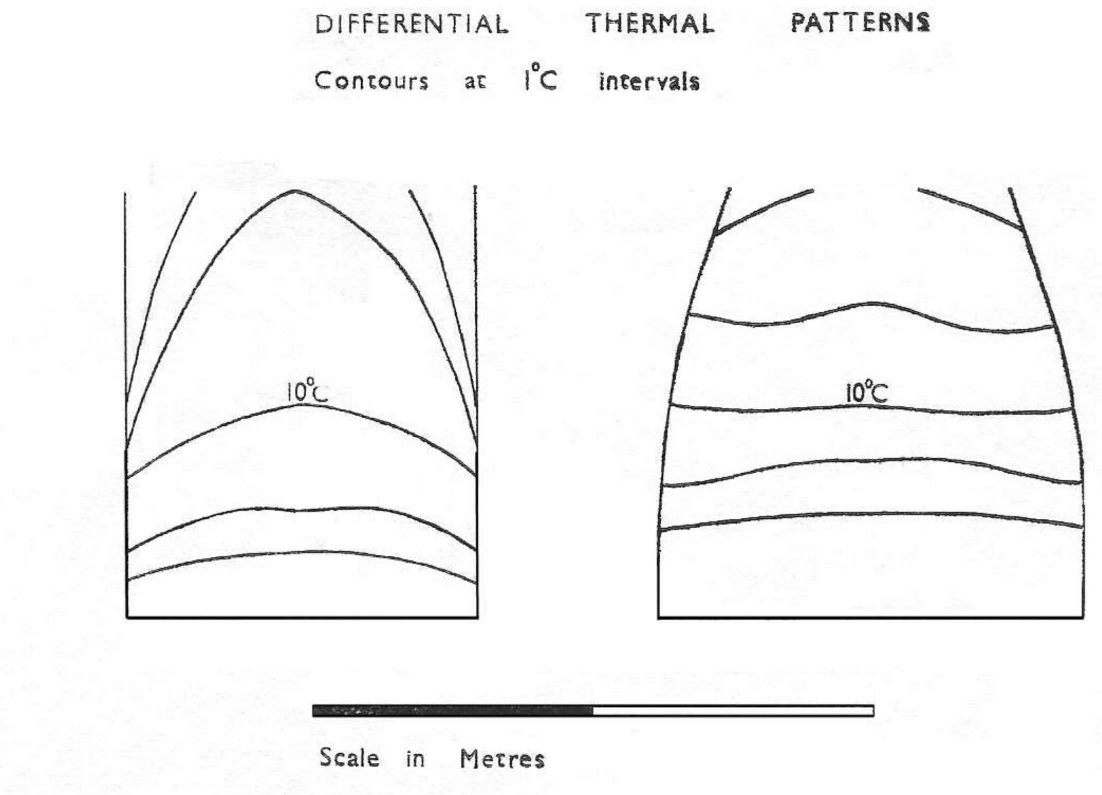


Fig. 3
Thermal patterns

In this connection it is relevant to mention in passing the four-post structures so often described as granaries. While it is not an unreasonable interpretation, it is necessary to consider how such a structure might have been used. Since grain stored in the loose mass exerts two-thirds of its weight in lateral pressure and only one-third in vertical pressure, a fact which caused the Romans to buttress their granaries, it is unlikely that the four-post structures, insubstantial in the above context, were other than sheds for storage containers as Bersu (1940) suggested. Further, such containers would be more carefully and safely stored within the domestic unit. Alternative interpretations for the four-post structures are discussed elsewhere (Reynolds 1972; Coles 1974; Stanford 1974).

The second possibility supported by the results from the experimental pits is that the pit-stored grain is seed grain for both local and commercial use. In further support the average size of storage pits with a capacity in excess of a tonne indicates that they are used for bulk storage rather than regular domestic use.

A further theory, that grain needs to be parched prior to underground storage, seems to be unfounded in the light of the results from this research programme. In fact, parching the grain is undesirable since the respiration cycle is vital for the production of carbon dioxide and the creation of an anaerobic atmosphere. Therefore, in any calculations there is no need to postulate any percentage of corn kept above ground for seed purposes but the extraction of grain from a pit during the winter suggests consumption grain may well be stored above ground… The parching process destroys not only the germination potential but also the malting qualities. The Celts stored grain in the natural state and manufactured beer. Indeed, the discovery of beer making and its attraction is relatively easy to understand once one has recovered grain from a flooded storage pit. The fumes alone are quite intoxicating.

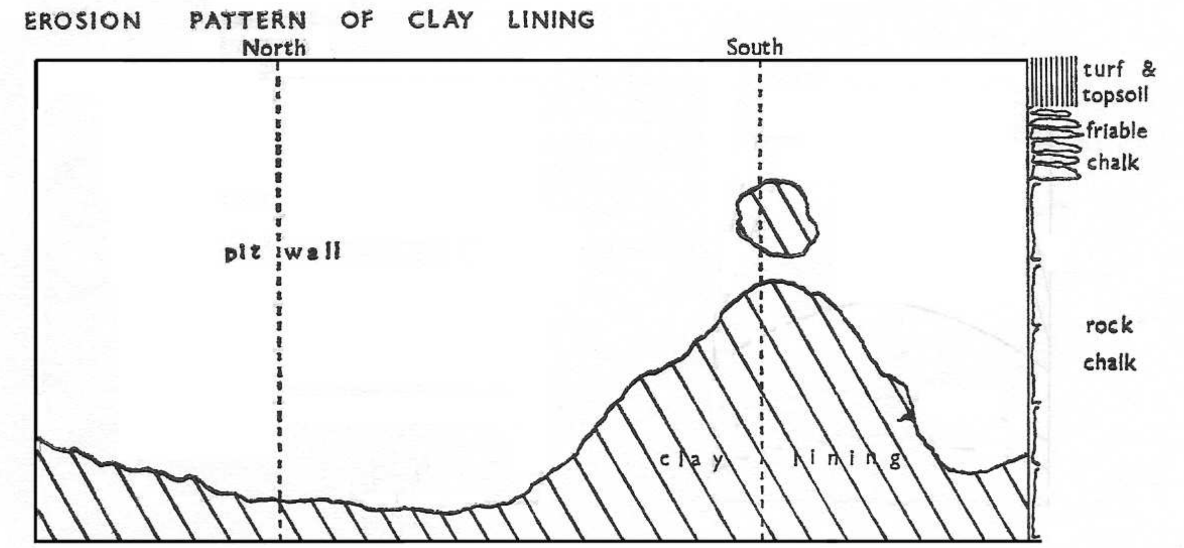


Fig. 4
Erosion pattern. Same scale as fig. 5

One particular object of the research programme has been to attempt to establish if there is any pattern to the thermal and gas activity within the storage pit. The methods used are described above. The results so far obtained would seem to establish two clear trends depending on the shape of the pit. Clearly the sample is not yet large enough to be statistically valid but a distinct pattern begins to emerge. Briefly the terminal shape within a cylinder pit is most frequently a beehive shape while in a beehive-shaped pit a shallow wave form is more common. Fig. 3 shows the typical sections demonstrating the two forms. This thermal pattern is closely imitated by the carbon dioxide concentrations. Greater variability is encountered at the top of the pit since it is affected more directly by variations in ground temperature and rainfall. Again the pattern is echoed by the germination results and the recovery of good edible grain. The implication is that the better shape on all counts is the beehive shape since it avoids the right-angle effect at the sealing point where the vertical and horizontal planes increase the ground-grain interface. The grain loss in an unlined storage pit consists of the grain skin which forms between the grain body and the pit wall. The skin is formed initially by germinating grain which produces the carbon dioxide. Once respiration ceases the germinating grains die and the adjacent grains adhere to them because of the moisture present. In practice this skin is usually 2 cm thick. Occasionally toxic microflora flourish but in insufficient numbers to contaminate the grain body. Given the dome shape afforded by the beehive pit this skin is of a relatively constant thickness since angles are at a premium. In the cylinder this skin increases considerably at the circumference of the pit top. The average loss for the experimental size cylinder pit is 5 per cent against a loss of 3 per cent for the beehive pit. As the pit size increases so the loss decreases since the volume to wall-area ratio changes proportionally. Size and shape, therefore, while not affecting the principle of the storage of grain, clearly are factors indicating efficiency and economic usage. The larger pits involve less wastage and the beehive-shaped pit is superior to the cylinder for the same reason.

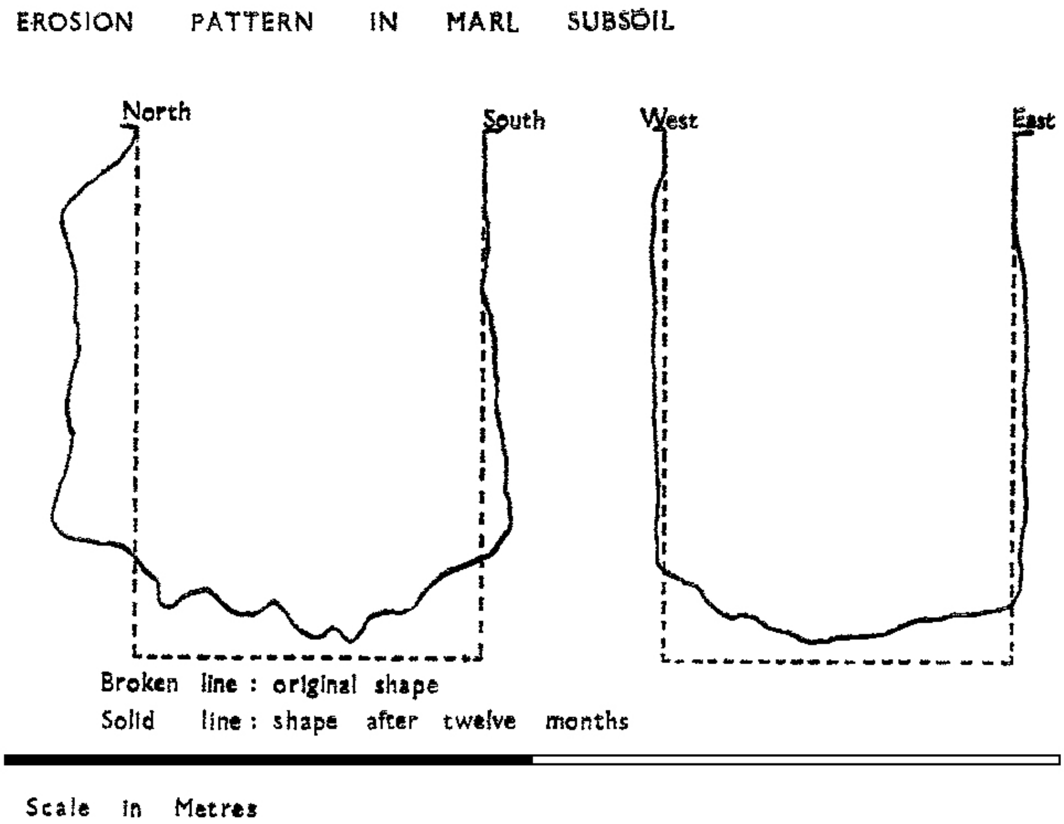


Fig. 5
Erosion pattern

Lining types do have a significant bearing on grain loss although the thermal and gas activity patterns remain similar. The best type of lining is simple basket-work where almost total recovery is achieved. However, a disadvantage of basket-work linings lies in the medium they provide for microflora activity in the second and subsequent seasons. The significance of this residual microflora infestation is at present being examined but the early results indicate some danger in the re-use of linings. Further, the use of basketry in beehive pits presents considerable difficulties (Bowen and Wood 1968). Archaeological evidence for such linings is rare but its absence could be the fault of the normal techniques used for pit excavation where sectioning is invariably employed. In the experimental cylinder pits the 'archaeological evidence' consists of a circle of small stake-holes 3-4 cm deep just inside the circumference of the pit floor – the evidence observable if the pits were excavated in layers.

Similarly, there is little evidence for clay linings. Possible keying holes for a clay lining were observed in a pit at Gussage All Saints (Wainwright 1973) but there may well be many more examples that have escaped observation. Clay-lined pits with only the pit walls covered do in fact store well, in that they provide an impermeable wall against the moisture in the surrounding subsoil, but the same 5 per cent loss with the grain skin is experienced. An attempt was made to fire a clay-lined pit, but the shrinkage of the clay caused it to crack and fall away from the pit walls. Limestone walling inside a pit provided no direct advantage or disadvantage over the natural rock.

However, firing a pit does have considerable benefits. Firstly, it dries a pit out thoroughly prior to storage so that the germination process only takes place beneath the clay seal. Its major benefit is the destruction of the residual colonies of microflora in the pit wall. On a chalk subsoil it also destroys the green algae (*Clorella vulgaris* and *Clorella ellipsoida*) that grow so readily during the summer months when the pit is open. Significantly, traces of an intense fire inside a chalk pit completely disappear after a few weeks of wind and rain; consequently, archaeological indications would be very slight. However, the experimental firing did, in fact, carbonize a few grains of barley that had lodged in the interstices of the chalk walls, a situation that may explain to some extent the discovery of carbonized grains in pits. Generally, the storage qualities of a fired pit are very good indeed and compare well with unlined pits under cover.

On a number of sites, pits have been discovered within the boundaries of houses. Often the excavator presupposes that the structure either pre- or post-dates the pits, but regularly both pit and house could have been contemporary. Experimental storage pits situated within reconstructed round-houses have, without exception, been entirely successful. The structure modifies the immediate effect of rapid change in ground temperature and completely removes the threat of excessive rainfall. Both temperature and carbon dioxide patterns reflect the protection given by a roofed structure.

The problem of determining the functional life of a grain storage pit is perhaps proving the most difficult of all. To date the most significant variables have been ground temperature and rainfall concentration. If the ground temperature is consistently higher than 5ºC the microflora activity within the storage unit is increased. If rainfall is consistently heavy, the subsoil becomes saturated and the moisture level within the unit increases. This again increases microflora activity. On occasions a pit has been completely flooded but not necessarily with disastrous results. Provided the grain is dried carefully on recovery, although all germination potential is lost, it is still edible. But total flooding needs to last until the moment of recovery for this to be so. Sometimes partial flooding has led to the loss of some of the stored grain, but remarkably the dry grain above the flood level has not only been edible but also retained its germination potential. Grain, however, which has been subjected to inundation for a short period only quickly becomes spoiled. Perhaps this situation may explain the abandonment of pits. In a winter which has a relatively short period of extremely wet weather, some of the outside storage pits could fail. The result of a failed pit, a mass of rotting stinking grain, could be a sufficient deterrent to the re-use of that particular pit although the failure is due not to the pit structure but entirely to the elements in that particular winter. Given drier conditions with evenly spread rainfall in the succeeding year, the pit would store excellently. If this is the reason for the abandonment of a pit, any theory aimed at estimating population size cannot logically include numbers of pits in its basic calculations.

A further theory is being tested at present. It is true to say that grain possesses all the elements of its own destruction when it is put into a pit. These elements are the microflora, the fungi and bacteria that live on the grain. Given the balance of temperature, moisture content and carbon dioxide concentration discussed above, the activity of the microflora in the bulk of the stored grain is minimized. However, in the grain skin which forms against the pit wall, microflora activity is much higher including certain toxin producing fungi (*Fasciculata asymetrica*) Residual colonies of these more active microflora remain in the pit wall after the pit has been emptied. The problem is to assess the concentration of these colonies after each successive storage period to discover if there is a significant increase. The first results indicate an increase in the infestation level but insufficient data have been acquired to prove or disprove the above theory However, firing a pit even for a short time successfully sterilizes it and simple cleaning to remove the green algae radically reduces the infestation level.

Finally, the experimental programme has steadily underlined the need to consider the pit as a structure. During each year of its functional life, two distinct phases affect it; first, the storage of the grain itself and the preparation involved; and, second, the phase during which the pit is open.

Mention has been made above of the probable need to clean the algae off the walls of a pit, a process which necessarily increases its capacity. Because it is easier to clean the upper part of a pit, a practice involving the scraping of the soil layers and root-bonded chalk strata, little increase in size results. However, further down the pit walls, because of the nature of the chalk rock discussed above, cleaning means a considerable increase in capacity. In terms of shape the cleaning gradually produces a beehive shape, the initial phase becoming apparent even after one year. Indeed this beehiving process is accelerated during the open period by the effects of erosion. Observations of erosion recorded for a marl pit left open for one summer period and for a clay lining within a chalk pit can be seen in figs. 4-5. Further the erosion follows a specific pattern with the north face of the pit suffering the greatest effect since it is this face of the pit which experiences the extremes of temperature range. Root bonding and compaction of the upper parts of the pit minimize the erosion effects. The end result again is a beehive shape. Once such a shape has been reached further erosion of the body of the pit is limited by the protection afforded by the shape itself. That the beehive pit is slightly better suited to storage is demonstrated above. The suggestion is that initially the arrival of this shape was a combination of the above processes. Once its improved storage qualities were appreciated, beehive-shaped pits were deliberately manufactured.

Proof that storage pits were, in fact, left open for the summer period could well be obtained if a sufficient sample of recorded sections of cylindrical pits of a north-south axis were available. In this way at least the erosion patterns could be considered and measured against experimental pits designed for this purpose. Ideally, four section drawings following the major compass bearings should be made for every pit including the position of adjacent structures which may have provided a shelter belt effect. Further the walls of a pit need to be recorded photographically since marks other than tool marks may be forthcoming, indicating the function of that pit. Observations of differential erosion patterns within Iron Age cylinder pits have been made by the author but much more recorded data are required before any definitive conclusions can be reached.

This paper began by posing specific questions about storage pits of the Iron Age Period. In conclusion the provisional answers to the questions so far attempted by the research programme are summarized below

1. While it is possible to store grain successfully in pits of a variety of shapes and sizes, the carbon dioxide and temperature patterns indicate the optimum shape to be of a beehive type. This shape also has the advantage of less wastage.

2. The achievement of a beehive-shaped pit can be seen to be the result of a combination of factors. A cylinder does erode into a beehive, and seasonal cleaning does accelerate the process. Given the advantages of the beehive shape, as outlined above, it is reasonable to postulate that deliberate manufacture of this shape ultimately took place.

3. Linings are not essential for the successful storage of grain. Certain linings offer some benefits but generally they are unnecessary. Basketry provides an excellent medium for microflora and has the added disadvantage that it needs regular replacement. Clay linings are impermeable but produce similar wastage figures to unlined pits. The best type of lining or pit preparation is an intense flame fire which removes excess moisture, kills virtually all the microflora and incidentally can be responsible for quantities of carbonized grain.

4. To seal a pit any malleable but impermeable material can be used. Clay has been used exclusively in the research programme but animal dung (*fimus),* cob or daub, or any impermeable solid cover the edges which are sealed, is perfectl6y adequate.

5. The implications of large storage jars or *pithoi*, fired or unfired, are of key importance. It has been proved beyond doubt that seed grain can be stored in a pit. Further the advantages of bulk storage and disadvantages of extracting small quantities at regular intervals suggest that this is the prime function of the storage pit. The jar, therefore, assumes critical importance for the storage of consumption grain. Further, unfired, leather-hard jars are in some ways ideally suited for this purpose.

6. Areas devoted to pit complexes can indeed figure in the general winter economy of the infield. Once all the storage pits are full and sealed there is no practical reason why such an area should be reserved.

7. The most significant fact so far to emerge from the research programme is that seed grain can be stored in an underground pit. The supposition that a proportion of seed corn needs to be reserved in special above-ground containers or structures is unnecessary. Rather it is necessary to store consumption grain in this way.

8. Finally the functional life of a pit would seem to be unlimited. Provided a balance of the essential factors for successful storage is maintained, there is no apparent reason for a pit to have a terminal life. Consequent upon the present phase of research, which is examining the residual microflora infestation in pit walls, this statement may be modified.

Throughout the experimental programme the need for more extended research not only into the problem of pits but into every aspect of Iron Age economy has steadily been underlined. It is only by thoroughly testing working hypotheses that positive answers are likely to be forthcoming. It is hoped by the author that the interim results of the research programme will be of use to archaeologists in their approach to excavation of pits and acquisition of prime data. Similarly it is hoped that results of excavations of Iron Age sites will be channelled back to the Butser Ancient Farm Research Project where it will form a significant part of research archive.

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