CONSERVATION

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Some field experiments in the removal of larger fragile archaeological remains.

SOME FIELD EXPERIMENTS IN THE REMOVAL OF LARGER FRAGILE ARCHAEOLOGICAL REMAINS

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1. INTRODUCTION

Field trials show that it is possible for the archaeological conservator to remove intact larger fired or unfired clay structures using relatively basic techniques. Local archaeological facilities are not always sufficient to resolve the problems presented by the occasional need to move large, well preserved, but fragile antiquities from the excavation site. This report discusses some basic principles involved in the safe transfer of a large 'mass liable to disintegration' (MLD), and outlines some techniques used in recent field experiments on the lifting and removal of structures in the 300–20,000 Kg range. Problems of lifting at short notice are mentioned.

Recent years have witnessed a remarkable increase in the worldwide threat of total destruction to many areas of archaeological interest. In the United Kingdom, extensive urban renewal, road construction schemes and the use of modern agricultural techniques have generated a large programme of archaeological excavations designed to recover information from a selection of the more important sites, which would otherwise vanish without a record of scientific investigation [1, 2]. Many thousands of artifacts are recovered in the course of these operations and undergo the normal laboratory examination and treatment procedures evolved for dealing with such material.

Certain artifacts, of course, need special care, and lifting techniques for their removal from the field are well established [3, 7]. Larger objects present difficulties. Examples typifying the problems involved are small structures such as kilns or metal working furnaces. By virtue of their construction, usage or age, few survive relatively undamaged [4, 8]. The greater majority yield useful archaeological information and, after systematic recording and documentation, will be destroyed. However, a minority of cases may warrant permanent preservation. On certain sites this could be highly impracticable in situ because of impending building construction or civil engineering works. In the rescue context of many current excavations it is therefore necessary to consider what rapid removal techniques are available if preservation is desired. Archaeological importance, rarity or completeness may indicate a case for relocation. However, when faced with the proposed transfer of a large crumbling mass, built perhaps of fired clay or unmortared stonework, the excavator may be forgiven if he initially regards the idea as impracticable. The occasional transfer of unstable material, of larger dimensions than those normally encountered, is usually achieved by sectioning into smaller fragments in order to facilitate removal. We have thought it useful to assess the difficulties involved in lifting subject matter as one intact mass, normally weighing up to 1500 Kg. A recent project has, however, involved preparation of a block of about 20,000 Kg.

At the lower end of the scale much may be achieved with basic resources but it is likely that a number of potential projects are never considered because of the apparently insurmountable problems involved. These are not always of a technical nature. The conservation techniques required are essentially straightforward and the main problems resolve themselves into questions of available finance, time and staff. Nowadays remarkable achievements are possible and house, temple or palace may be moved using the resources of modern technology. These large projects must be carefully preplanned by the architect and civil engineer and backed by suitable and formidable technical means. Events in what may be termed 'rescue archaeology' cannot always be pre-determined, and the archaeological conservator, who may be called upon at infrequent intervals to assist at field operations, generally has little more than basic equipment to deal with urgent cases. Nevertheless, even with limited resources, it is possible to remove successfully what we will define here as the larger 'mass liable to disintegration' (MLD). There are, of course, problems: certain soil and rock formations, the geometry and proximity of other vital archaeological features, and the shortage of time.

It has been mentioned that certain structures may be dismantled and lifted in sections which are of manageable proportions [3, 5]. In some circumstances, such as restricted access to the proposed museum display area, this may be the only solution. Subsequent reassembly and reconstruction will provide an acceptable compromise. Problems arise when handling certain structural fabrics, which may be so weak after prolonged burial that sectioning can produce serious losses or possible total disintegration. In these cases, total lifting techniques are advisable.

There is no real substitute for actual fieldwork and the experience gained from recent projects has been invaluable in assessing:

1. What can be achieved using basic equipment and materials.
2. Requirements for successful rapid operations.
3. Problems arising from compatibility of lifting work with any surrounding archaeological remains.

2. LIFTING – PRELIMINARY DETAILS

Work should preferably only go ahead after a close site examination and discussions with those responsible for the archaeological aspects of the area and those concerned with the after-care of the material. Conservation work resolves itself into three distinct phases:

1. Insertion of a rigid base under the MLD.

2. The boxing in and internal support of the MLD (in order to minimize vertical and lateral movement during transportation).
3. Detachment and removal of the boxed mass and its subsequent transport.

Major technical problems, if encountered, will probably occur in phase 1 and a flexible approach must be adopted to deal with unexpected soil conditions or methods of construction. Before work is started, it is of course important to consider the factors that will affect the progress of the operation. These include:

1. Condition of the structure (or object).
2. Time available for completion of work.
3. Type of rigid frame to be inserted.
4. Type of boxing and packaging required.
5. Soil conditions; methods and space available for introducing framework.
6. Space available to work in.
7. Access to site and availability of suitable transport.
8. Removal intact? or in sections? Availability of lifting equipment.
9. Liaison with site archaeologist and possible conflict with remaining current archaeological activities or remains.
10. Availability of suitable skilled team.
11. Consolidation requirements.
12. Weather; is a shelter required?
13. Final resting place; how and where will it be displayed?
14. Funds available.
15. Safety measures [9].

On urgent projects it is wise to consider these points at the earliest possible stage. Experience has shown that what may appear at first sight to be of minor importance may seriously affect the time required for completion of work.

Archaeological investigation naturally takes precedence on the site and, ideally, should be completed before the area is subjected to possible disturbance by the lifting operation. In practice, this is not always feasible. Archaeological evidence may still remain beneath, or close to the MLD, and if subsequent excavation is planned to continue on these levels, particular care must be taken whilst working in these areas. Normally, little conflict exists when the lifting of small subjects is undertaken, but with those of larger dimensions, greater caution must be exercized in preventing unnecessary disturbance of neighbouring archaeological features.

3. SOME BASIC METHODS

3.1. Insertion of a rigid base or platform

This is perhaps the most interesting phase of the operation. A large MLD must have a strong non-distorting base placed underneath it before any attempt at removal takes place, and it is evident that means must be provided to retain the mass intact whilst this work is undertaken. For a heavy subject it is obvious that an adequate base must be built up from a strong material capable of supporting the potential stresses and loading that will occur (one cubic metre of sandstone may weigh 2200 Kg). Concrete, steel and wood are possible choices. The need for a strong rigid section, capable of bearing high loads with minimal deformation, is perhaps best met by the use of steel plates or sections, preferably of a size that may be handled with relative ease. These supports must, of course, be introduced in a horizontal plane, beneath the MLD, through previously bored openings or small tunnels; or, if soil conditions permit, by driving them underneath the mass using a small hydraulic ram or screw jack. The areas around the structure may have to be fully or partially excavated before this operation. In due course the unstable mass will be supported on a carefully built-up platform of solid plates, the ends of which may rest on steel girders placed either side of the MLD. These girders can be subsequently raised up by jacks, thus detaching the mass from its original ground support. If suitably bolted or welded together, the main frame may be used as a cradle when the boxed mass is finally raised and transported.

Soil conditions will vary considerably from site to site and will often change beneath the structure. For this reason each project requires a very careful examination of the foundation layers together with an assessment of the capacity for survival of the material structure. If faced, for instance, with foundations of relatively soft sand, it would be preferable to attempt a complete underpinning, using an unbroken area of supporting steel plates. Where, however, the sub-structure comprises an interlocking, tightly-knit mass of stone rubble, it may be possible to insert steel plates only at irregular intervals, but in such positions that the total block is capable of being safely raised. Simple jacking equipment, widely available, is most useful under certain conditions in helping to insert the horizontal platform, especially when it is important to avoid damaging underlying levels.

3.2. Consolidation and internal support

Although well supported at its base, the MLD, when isolated from its surrounding soil matrix, will have a natural tendency to collapse because of its weight and size, especially if it is subjected to vibration and lateral stresses. This potential disaster may be averted by a certain amount of surface consolidation, and the subsequent application of a rigid reinforcing material capable of protecting the structure from complete degradation or serious erosion during transit. What is required in practice is the application of a rigid outer skin or box around the mass, and its encapsulation in a material capable of:

1. providing suitable protection and support;
2. being readily removable in the final reconstruction phase.

We have used strong plywood (18-25 mm thickness) for the exterior skin and, primarily for reasons of speed and weight-saving, have investigated the use of polyurethene foam systems as the embedding agent. Other materials, such as plaster of Paris or well-packed sand, soil, sawdust or lightweight cements, could possibly be utilized with effect, but the properties of polyurethane foams offer certain advantages, which in practice are difficult to resist.

The foam system adopted was Bibbithane RM 118*, a fluorocarbon blown, diphenyl methane di-isocyanate based, room temperature curing, rigid formulation, suitable for bucket-mixing operations. The material is resistant to fungal growth and has good load bearing capacity. Its use in the field has been found very acceptable although the desired physical properties are not fully attained at temperatures under 20°C. It is essential to use a barrier or release agent as polyurethanes have extremely good adhesive properties. Aluminium foil has been found to be most suitable. Some shrinkage may be expected in the final setting stage and must be allowed for. The warmed foam product produced in the exothermic reaction contracts as it cools and solidifies, often leading to the formation of a thin cavity between the face of the material and the protective foam filling. For this reason we have found it advisable to build the foam packing up in layers, allowing the previous mix to cool and contract, and then filling in the thin 2-5 mm gap, caused by contraction, with fresh foam.

Consolidation of the friable surface fabric is often essential, but this cannot always be fully achieved under field conditions. The foam, in addition to desirable weight saving characteristics, provides a material which can be removed at later stages with relative ease causing minimal damage to the fabric. For this reason it is of great value when areas of somewhat doubtful stability cannot be fully impregnated on site. Experience has shown that there is a need for the application of foam support at various periods throughout the duration of the removal operations. Difficulties in underpinning may necessitate the protection and embedding of a particularly weak section of the structure in order to prevent collapse during the work; any unwanted cavities appearing are readily and effectively filled with this rigid foam.

3.3. Detachment and lifting

Lifting is normally a straightforward operation and should present no particular problems providing that local lifting equipment is obtainable, and good access to the site has been arranged. In areas where no specialized plant is available, some improvisation may be required; hoists and many willing hands may be the answer. If lifting cannot be achieved in time for subsequent building operations to start, it may be possible to move the boxed structure horizontally to a temporary safe area by winching or towing on smooth ramps. The larger and heavier the final load, the more important it is to seek the advice of a lifting specialist who will be concerned with the last stages of the operation. Large cased structures will require specially sited lifting points incorporated into the design of the basic steel framework, and this must be under consideration at an early stage.

Our main concern, however, is with the initial detachment of the MLD from its site. It will have been protected on at least four sides by the wood outer shell and inner foam support, and it will be resting on the inserted platform. Several options are now open:

1. The large boxed mass and its platform could rest on a framework of steel joists which are joined together. Provided that the box is strapped or bolted in some way to this framework to prevent sideways slip, it will be possible to lift the whole in one complete operation.
2. Smaller subjects can be dealt with in a similar manner to 1 but problems arise if the two supporting girders on either side of the box are not firmly joined together by bolted linking sections.

The simplest approach is to lift the two side main supporting girders by means of jacks placed under each end. In this way the whole MLD is raised, on its platform, about 5 to 8 cm and is thus totally detached from its original matrix (Figures 13a-d). Through the gap created at the base, it will be possible to insert the wooden bottom of the containing box, lower the jacks and, finally, withdraw very carefully the plates of the inserted steel platform. Using this technique, it is possible to encase the MLD completely in a wooden shell. The wooden base thus inserted may be screwed to the adjoining vertical wooden walls or held firmly to the mass by means of strapping.

In a number of instances, however, it will be found extremely difficult to insert steel supports in a regular horizontal pattern because of underlying rubble foundation (Figure 15). As a result, the insertion of a flat wooden base which will mate to the four wooden sides is impossible. A solution here, after the top lid has been attached and the box totally filled with polyurethane protection, is to strap the metal plates of the platform firmly to the boxed mass after it has been jacked up. The total package can then be lifted and completely reversed. The subject will then be completely inverted but will rest on a solid bed of rigid foam, ready for transport.

Another solution is to raise the boxed mass with its firmly strapped base plates and to lower it onto the transporting vehicle, making sure that any rubble which adheres firmly to the boxed structure is well clear of the floor of the vehicle. A further possibility is to raise the MLD by jacking, to insert the wooden base and fill any spaces with foam before lowering (Figures 16, 17).

Varying site conditions will call for the judgment of the conservator in selecting the best approach. Most of the above techniques helped to provide solutions in the following field projects, which are discussed in detail.

4. EXAMPLES

4.1. Seventeenth-century glass furnace, central segment

The author first became acutely aware of the practical problems to be solved when asked to investigate the feasibility of removing, for public display, the remains of an early coal fired glass furnace [6]. It was understood

*Information on Bibbithane polyurethane foam systems is obtainable from Bibby Chemicals Ltd, Accrington BB5 2SL, England.

to be of a type hitherto unknown and first reactions were to use twentieth-century technology to lift and transport it intact. This optimism was soon tempered by the realization that there were a considerable number of formidable problems involved in such an undertaking. In 1971 archaeological investigation continued, revealing a structure with substantial surviving dry stone walling and an overall length of about 9 metres. With the resources and time available to the excavation team, it was decided that the best course of action was to record fully and dismantle the stone walling and archways for future reconstruction at the museum. This method of removal appeared to provide a most acceptable procedure for future rebuilding of the structure in the confines of the display gallery.

Although dismantling and crating of the stonework could go ahead, one embarrassing and unwieldy section which existed in the centre of the structure pointed to the need for an approach based on normal techniques of lifting smaller archaeological objects. Our problem was a siege platform upon which the crucible vessels had rested in the furnace. A large proportion had survived and it was essential to retain it in its entirety. The brief, therefore, was quite simple: means had to be devised to detach and protect the siege core for transport to the museum 30 miles away. First thoughts were not encouraging, as this part of the structure was composed of a fused and partly friable mass of sand, slag, stone and crucible remains which were 'welded' on to the central stone flue.

In the event, the main part of the operation proceeded smoothly in a matter of days, the actual time span being about four weeks as a consequence of the unavoidable archaeological investigation required. This is a matter which cannot be overstressed. The interaction of lifting operations and the detailed careful excavation of nearby areas may be complex, and close liaison and planning at the outset is essential. If an intricate removal exercise is planned during primary excavation, a rigid timetable may be rendered quite inoperative by fresh archaeological discoveries. The scheme adopted followed the pattern:

1. Initial surface consolidation of soft and powdered areas using a solution of polyvinyl acetate in an ethanol/acetone mixture.
2. Application of aluminium foil to all exposed surfaces (Figure 1).
3. Construction of a strong wooden box around the central siege mass and application of polyurethane foam to fill all interior cavities.
4. A series of holes were made using conventional masonry drills with extension pieces, at the boundary (interface) of the fused base of the siege mass and the upper surface of the flue stone walling. These circular openings served as guide channels for a series of horizontal steel channel support sections (5 cm by 2.5 cm), which were sharpened to a V-profile at one end and driven in by simply tapping the other end (Figure 2).
5. At this stage, the solid mass was protected at the sides and partially severed at its base by the steel inserts. Detachment was achieved as follows. The surrounding areas of trenching were carefully filled, using soil and wood planks, to a level where it was possible to place two small steel girders under and either side of the inserted steel channel supports. These girders were then raised by jacks placed underneath, resulting in the lifting of the steel supports and hence the boxed, protected siege mass.
6. The wooden base of the box was inserted into the newly created gap caused by the upward displacement of the siege mass. The box was then surrounded by slings and lifted by a mobile crane.
7. The metal channel supports were now easily extracted, and the packaged mass then inverted with the aid of crane and manual effort, so that the previously attached lid now became the base. Our original intention was to encapsulate the siege platform completely with the polyurethane foam but in the final stages of filling the wooden casing we discovered the supply of the material was exhausted. A relatively small space remained to be filled and this was therefore packed with fine soil before the lid was positioned.

4.2. A second-century Romano-British pottery kiln

In 1973, archaeological investigations prior to the implementation of a major road improvement scheme were undertaken on part of a Roman settlement near Ipswich, Suffolk. Amongst the features revealed was a second-century pottery kiln which, being reasonably complete, had some claim to preservation, preferably for public display. At a short site meeting, two weeks before the road construction unit was due to commence operations, it was decided that an attempt would be made to remove the kiln intact in one swift operation.

An intense period of activity then began. Careful measurements and estimates were made and a steel raft constructed which could be inserted in sections under the structure (Figure 3). The main frame was designed so that it could be bolted together in situ. Because of the limitations of space inside the chamber, there being just sufficient room for a single person to work, it was reluctantly decided to remove a small surviving central clay pedestal by conventional boxing, and lifting it vertically through the top of the kiln. Once completed, this operation enabled us to obtain the improved access that was required for the subsequent treatment of the inner surface of the structure. It also helped to provide space for the insertion of the central steel H-beam, the two outer girders being positioned in two side tunnels which were excavated carefully in the clay and sandy gravel soil (Figures 11a, b). Across these longitudinal side girders, short steel plates (10 cm wide, 1 cm thick and 75 cm in length) were inserted, with their ends resting on the top of the outer girders and the main central beam. The plates were placed in this position by using screw jacks which were located horizontally on both sides of the kiln.

The firing chamber had been constructed of clay and it was clear that certain areas required some form of consolidative treatment. As little time was available and much work could be completed at a later restoration phase, it was decided to spray the most affected areas, which were in danger of becoming detached, with a solution of polyvinyl acetate in ethanol. This provided reasonable short-term protection. The interior surfaces were covered with aluminium foil and the whole cavity filled, in several operations, with polyurethane foam. The stabilized structure was enclosed in a strong wood box, all remaining cavities being filled with foam (Figure 4).

The whole was then strapped by a small steel frame to the main steel lifting platform. This was necessary in order to counteract the results of any possible sideways tilt during the lifting and unloading operations. On the final day of the project, the whole mass was raised swiftly and uneventfully, loaded and transported six miles in two hours to the museum store (Figure 5).

4.3. A small early iron furnace

Excavations at a large ironstone quarry in Northamptonshire, extending over a period of years, had revealed an Iron Age settlement, Roman agricultural activities and numerous remains of iron smelting furnaces. These structures, set in pits dug in the natural bedrock, provided evidence of iron-working activity that had continued into the Roman period. Out of a group of about 30, one small furnace was found in a reasonably complete condition towards the final stages of the 1974 excavations, and it was decided to attempt to raise it in one complete operation.

The site was situated on a bed of Upper Lincolnshire Limestone. Surface soil conditions were variable. The area we were concerned with consisted of limestone rubble, marly clay and sand mixture with a large unsuitable natural cavity existing beneath the structure, although this was not discovered until the latter stages of the operation.

One of the objects of this exercise was to assess the practical aspects of removal from a matrix such as the limestone rubble in which the structure was embedded (Figure 6). The clay fabric of the small firing chamber was friable and liable to complete disintegration after its prolonged burial. Its base was soft and appeared poorly fired. A brief visit to the site a month before the main work was planned to commence indicated what equipment was required and also provided an opportunity for first aid treatment. As there were doubts regarding the stability of the circular clay walling, it was protected by lining the interior surface with thin aluminium foil and then filling the chamber with polyurethane foam (Figure 7).

On our return to the site, the main problem appeared to be the insertion of a rigid base. There was, in fact, no alternative but to excavate small tunnels beneath the mass and remove the rubble (fragments up to 30 cm in diameter) by levering, chiselling and trowelling. This somewhat crude but vital exercise was happily completed in a shorter period than originally estimated. Each tunnel was started from both sides of the structure. When completed, metal support plates (120 cm by 10 cm by 1 cm) were inserted and held in position by wooden chocks (Figure 8). Any interspace between the base of the structure and top of the steel plate was filled with polyurethane foam placed in a polythene bag. It was thus possible to place the mixed liquid components in relatively inaccessible 'cells' which became potential load-bearing columns after the foam had reacted and solidified.

In this way the block containing the furnace was finally supported on several steel plates, as well as resting on some isolated rubble 'pillars' which still remained uncut. The plates themselves were carried on two steel box sections (10 cm by 5 cm). The total mass was then encased in a 2.5 cm plywood shell, filled with foam, and raised by the action of hydraulic and screw jacks placed under the two main box sections. Final detachment was achieved by passing ropes around the base steel plates and the box, and then lifting onto the ground surface using a mobile quarry crane with the assistance of its maintenance team (Figure 9). We then reviewed the next phase of the operation. Time was short and there was a 100 mile journey to the museum store. Examination of the furnace base showed that it was going to be an extremely tedious procedure to insert a wooden base, as was the original intention. There was, in fact, no real need to box completely. If the mass were reversed, time would be saved on site and a concrete base could be constructed at a later date when the display stage was reached. It would also afford an opportunity in the meantime for an examination of the furnace base if this was required. Accordingly the boxed structure was inverted, loaded and transported with remarkably little difficulty (Figure 10).

4.4. Prehistoric burial mound

Lifting techniques in archaeological investigation are not necessarily confined to subjects destined for permanent preservation. Soil blocks containing complex assemblages of highly deteriorated artifacts are occasionally sent to the archaeological laboratory for more detailed examination. A recent field exercise (currently under way) illustrates both the preservation and the investigation aspects that may be involved.

The central grave pit of a prehistoric burial mound in Lincolnshire had been located during excavation and the laboratory was asked to provide aid for the removal intact of a rare and interesting planked wood structure preserved as a friable mass of charred wood. Our two main objectives were:

1. To preserve the remains intact for possible future display.
2. To examine the lower surface for further information on methods of construction and use.

Soil conditions appeared to be excellent for a routine lifting operation but the plan had to be abandoned when it was realized that the wooden structure overlaid a pit containing important archaeological evidence. The next approach appeared to provide a satisfactory solution to the problem of detailed excavation underneath the very fragile wooden remains:

1. A larger soil block would be detached (1.8 by 1 by 1 metre).
2. The soil block would be carefully protected and completely boxed. Once detached it would be inverted.
3. Detailed archaeological excavation could then proceed on the pit remains with recovery of the desired information. The planked structure remaining, and in one piece, could undergo further laboratory examination and conservation.

Figures 14a-c illustrate the proposed approach, which had to be postponed because of extremely poor weather conditions.

5. CONCLUSION

A small number of field trials on difficult subjects has shown that successful results are possible in lifting operations using basic equipment. Further work is required on techniques for rapid completion of work. Recently preparations have been completed for raising a kiln of about 20,000 Kg weight (4 by 2.5 by 2 metres), and it is hoped to report on this exercise later in 1975.

ACKNOWLEDGEMENTS

Throughout these projects, which depend on teamwork, the author has been greatly helped by advice and assistance from many interested individuals. Work on the seventeenth-century glass furnace was undertaken by staff of the North Western Museum and Art Gallery Service, to whom grateful thanks are due. Other projects listed above have been assisted by the Ancient Monuments Laboratory Conservation Section.

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Figure 1. Remains of a siege platform from an early seventeenth-century coal-fired glass furnace, showing the application of an aluminium foil barrier prior to embedding in a polyurethane foam.

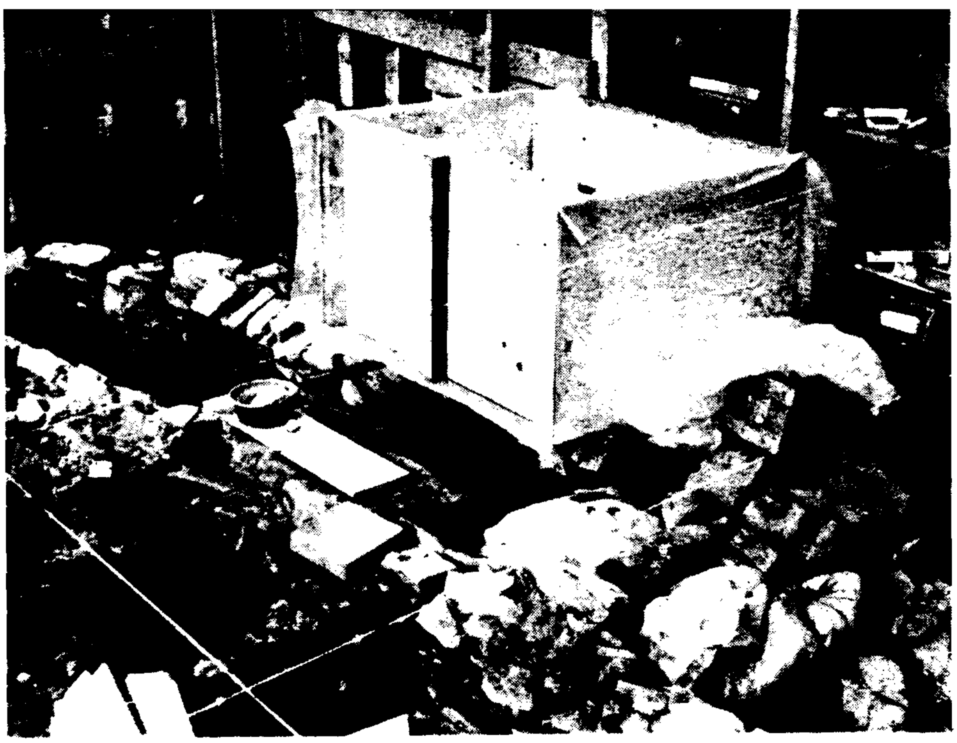


Figure 2. The first two steel channel sections of the supporting stage are inserted at the base of the protected, boxed, siege mass.

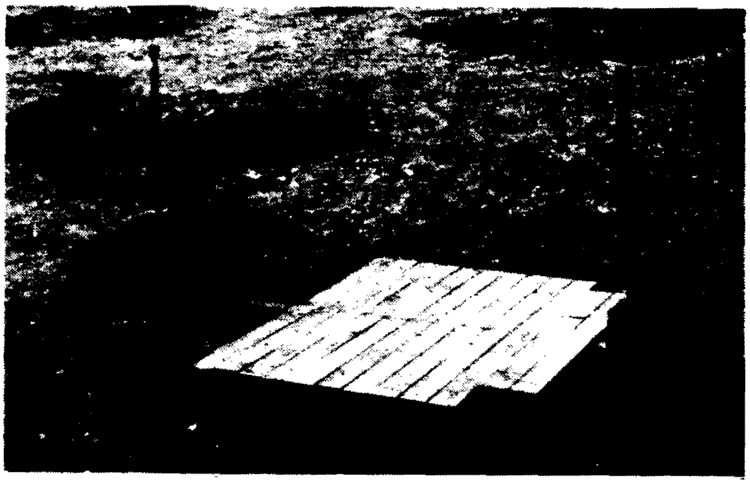


Figure 3. Steel platform prior to insertion under the pottery kiln, which is visible in the background. The two main support girders are 220 cm in length. (Photo: Ancient Monuments Laboratory).

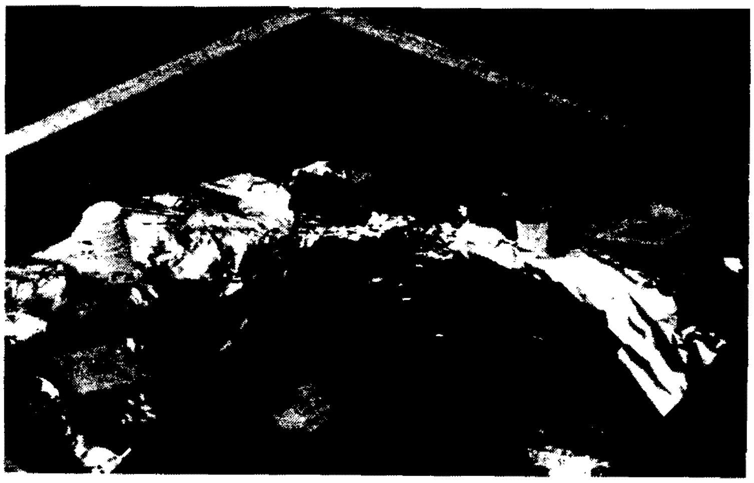


Figure 4. The kiln walls, covered with aluminium foil and in a wooden box, are embedded in polyurethane foam. (Photo: Ancient Monuments Laboratory).

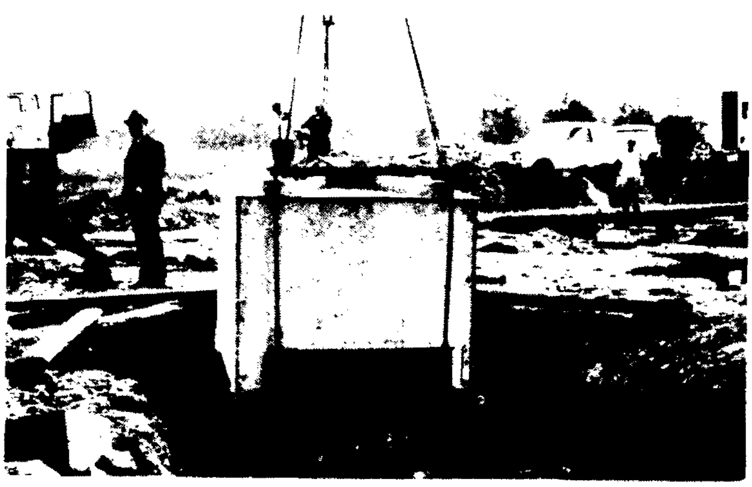


Figure 5. Boxed kiln is lifted. Note small steel frame which provides the lifting points. (Photo: Ancient Monuments Laboratory).

Figure 6. Rear of isolated furnace block shows the extent of rubble matrix. Photo: Ancient Monuments Laboratory).

Figure 7. The small iron furnace, after being isolated from adjoining rubble matrix and protected with polyurethane foam, is ready for the underpinning stage. (Photo: Ancient Monuments Laboratory).

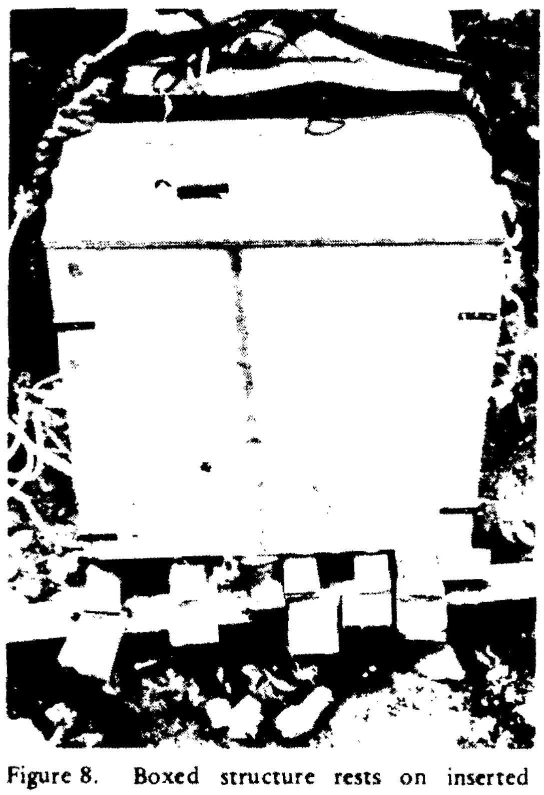
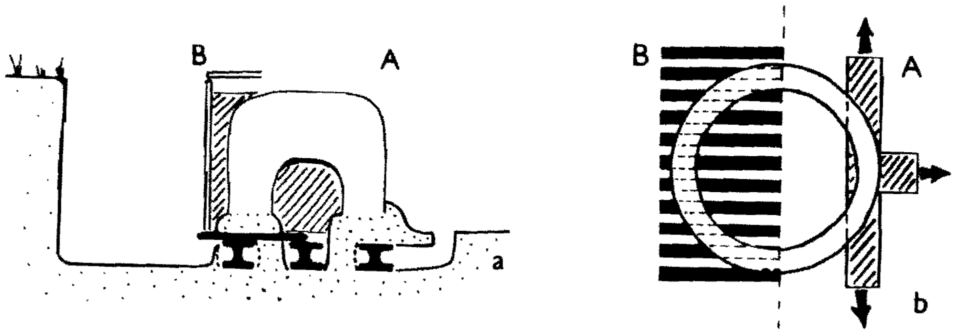


Figure 8. Boxed structure rests on inserted steel plates. Note wooden chocks between plates and main steel side supports. (Photo: Ancient Monuments Laboratory).

Figure 9. Furnace is lifted to ground surface; plates have been strapped to wooden box. (Photo: Ancient Monuments Laboratory).

Figure 10. Boxed structure is carefully inverted before metal plates are removed. (Photo: Ancient Monuments Laboratory).



Figures 11a,b. Stages in underpinning kiln:
A. Insertion of steel girder, with plan showing extraction of soil from tunnels.
B. Plan of kiln structure, showing polyurethane foam and wooden box with steel underpinning.

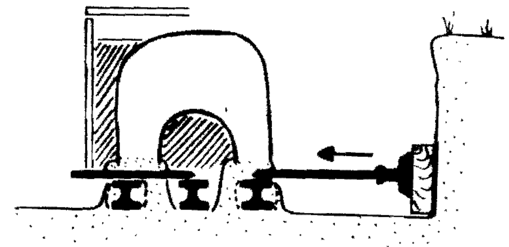
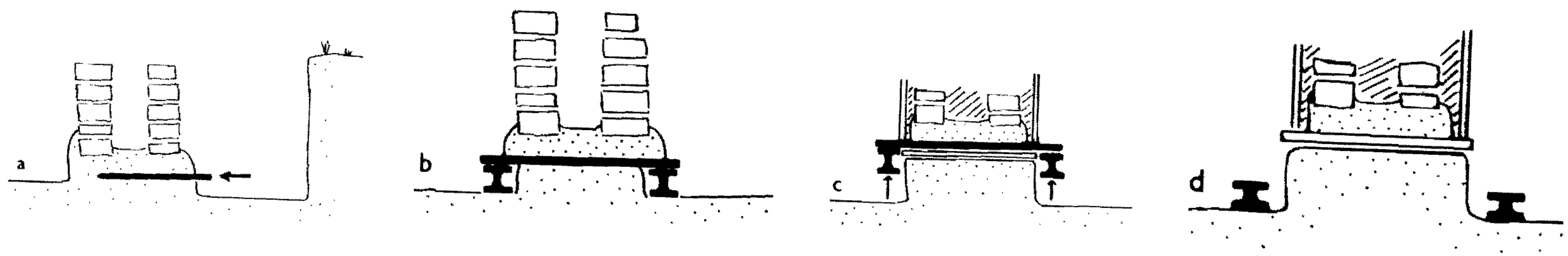
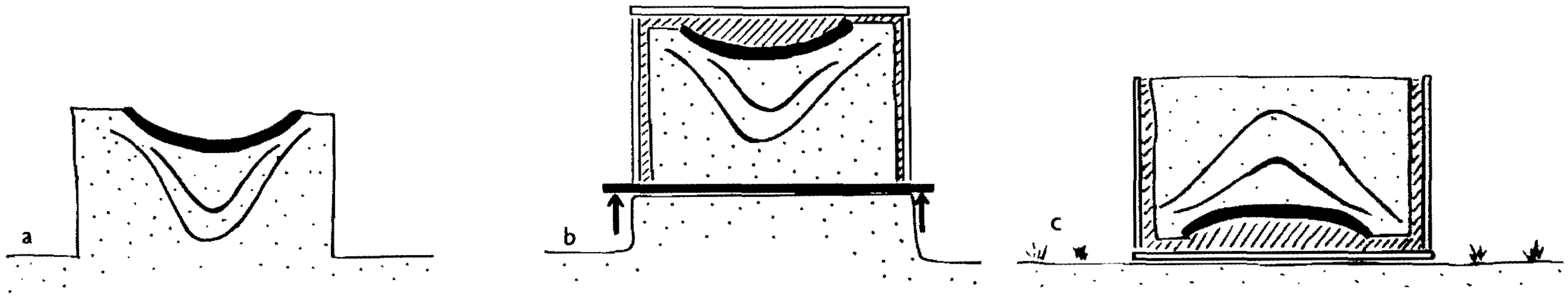


Figure 12. A method of inserting a metal support plate using a simple jack.



Figures 13a,b,c,d Stages in boxing a structure.



Figures 14a,b,c Stages in detachment and inversion of a soil block.

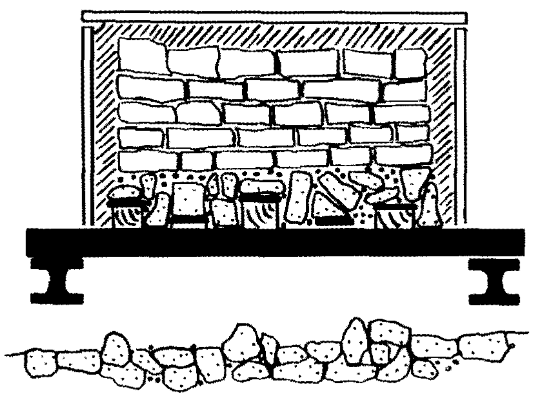


Figure 15. Structure on rubble foundations has been detached. Metal support plates rest on wooden blocks on main side girders.

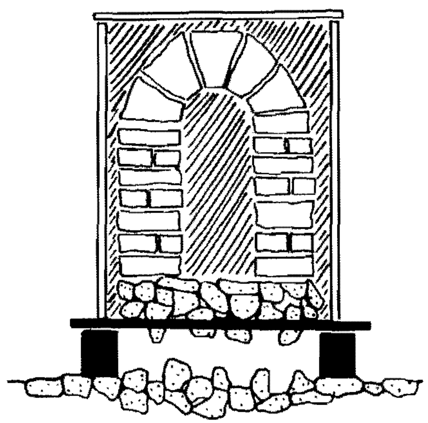


Figure 16. Rubble foundation is difficult to extract and rests between metal plates which support the structure.

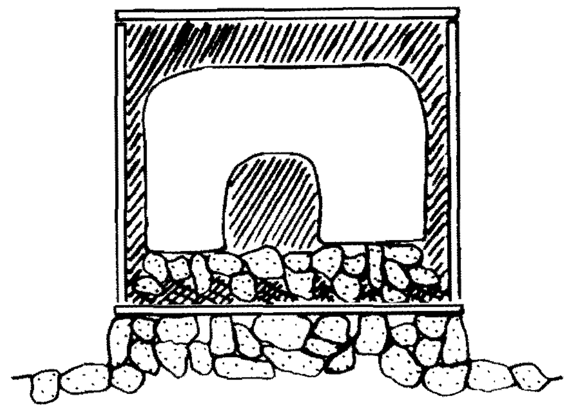


Figure 17. Boxed structure has foam or concrete base inserted in final phase of detachment.