Archeological Fieldwork, Catalhoyuk – Turkey, Summer 1996:
Experiments in the Stabilization, Detachment And Transfer of Neolithic Mud-Brick Wall Panels

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THE PROJECT

This text and the accompanying drawings and photographs document the experimental fieldwork in the detachment of Neolithic mud brick wall panels at Catalhoyuk, Turkey during the summer of 1996.

This work was done in parallel with experiments in the stabilization and preservation of the associated wall plasters and paintings in several areas of the excavations. The team undertaking the experiments in wall-panel detachment was Lindsay Falck and Caitlin Moore of the Department of Architecture of the University of Pennsylvania and Evan Kopelson of the program in Historic Preservation also of the University of Pennsylvania. The experiments in consolidation and preservation of the wall surfaces were undertaken by Constance Silver of Preservar Inc. of New York and Frank Matero and Evan Kopelson of the program in Historic Preservation of the University of Pennsylvania. Orin Shane of the Department of Anthropology and Archaeology of the Science Museum of Minnesota, assisted the team with general logistics of supply and transportation.

Both the plaster preservation work and the experiments in wall panel detachment were funded by a grant from the World Monuments Fund and were undertaken within the overall archeological program at Catalhoyuk under the direction of Ian Hodder of Cambridge University. The archeological fieldwork coordinator was Roger Mathews, Director of the British Institute of Archeology, Ankara. Fieldwork leader in the area in which the wall detachment experiments were conducted was Shahina Farid.

The experiments in the detachment of very large scale, 9,000 year old, mud brick wall panels were intended as a first phase of ongoing work, in later seasons, which would lead to the eventual detachment and removal of an entire "room" of wall panels. These panels would then be reassembled on or off site, so as to fully describe the art and artifacts of a typical Catalhoyuk interior space. Controlled removal of the walls means that earlier levels of building, known to exist in underlying layers, can be exposed for study without the demolition and loss of the walls above, which has been the case in the past.

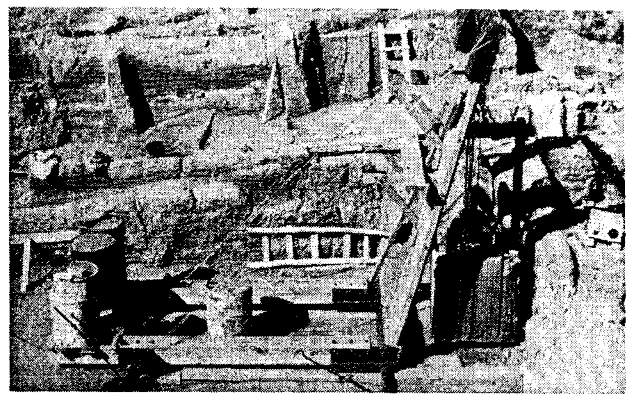

Fig. 1. Lifting rig with detached wall panel suspended in steel lifting harness. September 23, 1996. Photo Lindsay Falck.

The fact that the work done in the first phase, during August and September of 1996, was totally successful in meeting, the goals set bodes, well for ongoing work phases. The success of the first phase of work was across several areas of technical achievement, all being "first times" in terms of fieldwork of this nature.

Firstly, the working geometries of the drilling and hoisting frame, known as the "rig", accommodated all possible conditions of drilling and lifting likely to be encountered in ongoing work. These geometries worked for a corner condition, a high wall next to a low wall, a leaning wall condition, and where a wall panel is above or below the adjacent working level.

Secondly, the rig proved to be highly maneuverable with very little physical effort. It could be rolled forwards or backwards with light rotational leverage on the roller tubes. It could be slid sideways on the roller tubes with equal ease. Slewing of the rig was also possible by contra-rotation of the front and rear roller tubes and by sliding diagonally the opposite ends. This threefold directional maneuverability is essential for working within the tight confines of a contained "room" or working area.

Thirdly, the lifting harness component performed all its intended functions highly effectively. The harness could be positioned at an angle off the vertical, to suit the lean-out of

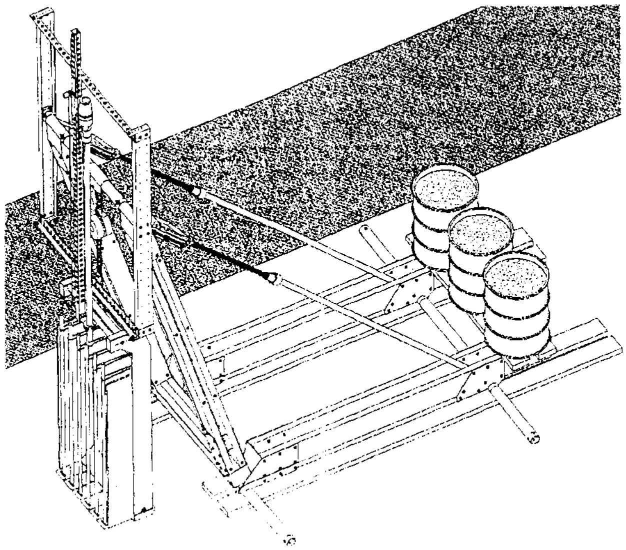

Fig. 2. Isometric view of lifting and drilling rig. Drawing- Caitlin Moore.

the wall. It was able to accommodate and hold, without any new cracking, a wall panel that was seriously undercut on one lower corner. The center of effort of the lifting point at the top of the harness could be adjusted laterally, in a direction parallel to the face of the wall panel, so as to balance the wall when lifted, to avoid any lateral break-away in the final stages of detachment drilling. The center of effort of the lifting point of the harness could also be adjusted in a direction at a right angle to the wall face so as to hold the wall panel in vertical equilibrium during all stages of detachment drilling. These two factors were vital for avoiding cracking and breakage at the center or edges of the wall panel during detachment.

Fourthly, at the foot of the harness, the design of the lifting-support-spades, the sequence of their insertion into the slots cut into the bottom of the wall panel, the amount of uplift pre-stress loading exerted on them during release-drilling and the way in which the slotted ends of the spades received the eccentric pins of the locking cam-tubes, all worked exactly as planned and resulted in crack and damage-free removal of the wall panel.

Finally, the release-drilling system worked very well considering the unexpected density and moisture content of the wall, particularly in the lowest levels of the panel being removed. The drill ran remarkably true, down the full length of the drill-holes. The speed-control rheostat and voltage transformer, custom built for the project in Ankara, performed exactly as needed, giving a complete range of drilling speeds, as required by the different densities of brick and mortar in the upper and lower substrata and the various levels of moisture content encountered. The hand-winch system for lowering and raising the drill worked well with the double-purchase system used, where drill movement was at half the speed of hand movement, giving very accurate pressure control on the drill bit end.

The fact that the end of the drill-tube had to become the cutting edge, with hand cut teeth in it, to substitute for the tungsten carbide cutterhead lost in a severe sand-storm, ended up as an advantage because the reduced cutting diameter of the hand cut teeth held the upper part of the tube in tighter vertical alignment, giving less run-out over the length of the drill hole.

PROJECT DIARY

The Idea

The idea for the project originated a year prior to the 1996 fieldwork experiments when Ian Hodder and Frank Matero discussed the possibility of preserving the architectural fabric of the Catalhoyuk excavation area by detaching and transferring large sized panels of the mud brick walls of individual "rooms," after excavation and recording all of the surface features. These panels could then be reassembled on or off site with a minimum disruption of the wall and painting surfaces, resulting in a more integratedpresentation of the architectural features and room interiors. A parallel advantage of being able to detach large panels of wall would be that they could also be transported to a field or centralized laboratory, where the slow and delicate procedures of de-layering the painted plaster layers, sometimes over a hundred layers deep, could be undertaken in controlled humidity, temperature and lighting conditions.

The Design Challenge

In September of 1995, Frank Matero approached Lindsay Falck to devise a system for detaching and transporting mud brick wall panels at Catalhoyuk. Available archeological and engineering research documentation indicated that the removal of large mud brick wall panels of such age and expected fragility had never been attempted before. Thus there was neither precedent for research reference nor even any ideas as to how this might be done. The Architectural Conservation Laboratory of the University of Pennsylvania had some small samples of plaster and fragments of mud brick taken the year before from the site. These were completely desiccated and were therefore extremely fragile, being easily crumbled between fingertips. With this evidence it was thought that not only would the plaster faces need consolidation, but also the whole volume of the plasters and adjacent mud-brick substrate would need to be impregnated with some form of consolidant to avoid cracking and crumbling during detachment. The design of the impregnation system therefore ran parallel with the design of the detachment and transfer system.

First Design Proposals

First thoughts for the detachment system were based on the use of a "plunge band-saw." When later reports on the condition of the mud brick walls predicted that there might be higher moisture content and greater cohesive strength within the walls, this system of vertical band sawing was superseded by a system where overlapping drill-holes, down the back and sides of the panel, would be used to detach the wall. The drilling system became the basis for the design.

Apart from the problems of impregnating and detaching the wall panels it was also necessary to devise a system for lifting the panels out of the excavation "room" and transporting them to a laboratory or a museum site.

Because of the fragile nature of the surrounding archaeological excavation areas, the use of a large wheel-mounted mobile crane seemed to be inappropriate for lifting the panels which together with the lifting harness, could weigh between 1000 and 2000 kilograms (approximately 1.2 to 2.4 tons)

The solution, as eventually proposed for use on the site, was to combine the drilling and detachment system with the lifting and transfer system by using a pivoting framework to which both the drill-unit and a hand operated chain hoist with lifting harness could be attached. This is the system shown in the 24 work-phase drawings, which was included in the final report, but not in this paper.

Design Development

The overall system was developed after detailed discussions with Frank Matero, Connie Silver and Orin Shane, during the period from September 1995 to April 1996.

During May of 1996 Lindsay Falck was joined by Caitlin Moore, a 1996 graduate of the Master of Architecture program of the University of Pennsylvania to develop the systems into detailed design drawings and to fabricate some of the components for the drilling and lifting rig prior to dispatch to Turkey.

Working drawings of all components were made followed by full scale "lofting" or setting-out drawings made on large scale plywood sheets from which three dimensional plywood templates for all the sheet steelcomponents were made. These templates were carefully checked to ensure that both the functional needs and the fabrication techniques to be applied in Turkey were fully resolved. When completed the templates were taken apart and packed to become airline luggage. The very large templates for the drill harness, some parts being over nine feet long, were cut up into smaller sized interlocking pieces for re-assembly in Turkey where they would become the working templates for steel fabrication.

Component Fabrication in Philadelphia

At the same time that these templates were made, all the brass, stainless steel and mild steel components for the drill-rig drive mechanism and vacuum extract housing system were machined and made by Caitlin Moore, Lindsay Falck and Buddy Borders of the Rittenhouse Laboratory of the University of Pennsylvania. The aluminum drill frame members were made by Caitlin Moore and Lindsay Falck with assistance from Samuel Mason and Gustav Kamp, two University of Pennsylvania students. Much valuable assistance was received from Dennis Pierattini and Brett Balogh of the University of Pennsylvania Graduate School of Fine Arts Woodshop. Aluminum Shapes Inc. of Delair, New Jersey generously donated all of the aluminum extrusion sections needed for the project. McKnight Steel Inc. donated the short lengths of stainless steel tube required for fabricating the drill-drive unit and the vacuum extract sleeve for the drill.

Fig. 3. Fabrication of plywood template for steel lifting harness. University of Pennsylvania workshops. Caitlin Moore. Photo Lindsay Falck.

Transport to Turkey

All these components for the drill rig and the templates for the lifting rig parts, weighing some 160 kg (350 lbs.). were taken to Turkey as airline baggage by Caitlin Moore and Lindsay Falck. British Airways generously transported this overweight and overlength luggage to both London and then on to Istanbul without any surcharge costs.

Consultation in London

One of the main reasons for traveling through London was to enable Kevin Falck, a mechanical engineer with Lotus Engineering, who had acted as consultant to the project from its earliest phases, to do final checking of all the proposed structural sizes, strengths and required welds, torsional loads etc. on the lifting spades and harness structure etc. Carl Falck, a practicing Architect in London who had also acted as consultant throughout the project assisted with adjustments to the drill guide-bearing component. The stainless steel cables, turnbuckles, shackles, and cable-strops required for the tension members of the rig, to sustain it in the 15-degree lean-over position, were purchased from Spencer Rigging of Cowes, Isle of Wight.

Work in Turkey

Material Purchases

The first days in Turkey were spent in Ankara purchasing hand tools and materials for the project. A local electrical supply firm was commissioned to fabricate and supply the transformer/rheostat unit for the American made Milwaukee drill.

On arrival at Catalhoyuk all equipment was unpacked and the templates for the required steel plate parts of the rig were re-assembled. Aygul Kaynak Atolyesi, a firm of steel fabricators in Cumra, a nearby farming village, was contracted to make the steel parts, sized from the plywood templates, thus avoiding any Metric/Imperial and language communication problems. Steel plates and angle sections were purchased in Konya, a large industrial town, 50-km from Catalhoyuk and the steelwork put in hand. The heavy wood members for the rig were also ordered from suppliers in Konya.

Assembly on Site

Once the heavy wood members arrived at the site, Caitlin Moore and Lindsay Falck started the cutting and assembly work on the rig. Evan Kopelson joined the assembly team at this stage. Ian Hodder had identified an area of the dig site where the first trial tests of the wall panel removal system could be made on a wall area which was intended for hand demolition and removal, thus allowing freer experimentation than if the wall was meant to be preserved intact. The work area for the rig was very accurately leveled and the baseboards set into position.

The steel components were delivered to the site and erection of the rig frame was started. Once the rig was completed it was realigned to its exact working position. Evan Kopelson, Connie Silver and Frank Matero completed final work on stabilization of the surface of the wall panel to be removed. A heavy capacity electrical supply cable of 350 meters length had to be purchased in Cumra and installed, on site, to bring power for the drill, vacuum extractor and lighting for night work, to the working area of the rig.

Setting the Lifting Harness

The steel lifting harness was then set in place against the face of the wall panel and the wood framework and plywood backing to support the wall panel was constructed. Side and base closure panels were cut to match the exact edge and base profiles of the wall surface. A layer of plastic sheeting was inserted against the wall face to protect the surface and the void filled with sand to support the panel against the lifting harness.

It had always been intended that expanding urethane foam would be used to provide the support bed for the wall panel. Unfortunately no local suppliers could be found for this material so sand was used as a substitute. The sand was satisfactory while the harness and wall panel was in a vertical position, during the detachment sequences. However, the sand did not perform at all well when the harness and frame were lowered into a horizontal position, when the rig was being taken down at the end of the project, and serious cracking occurred when the base support spades were removed.

For this test it was decided that it would not be necessary to impregnate the wall panel with a consolidant solution. On-site observations indicated that the mud brick and mortar joints were more cohesive than had been anticipated. The moisture content of the walls was also much higher than expected, particularly at the base of the walls where there was rising damp from the surrounding ground surfaces.

Fig. 4. Steel cap-beam assembly, Cumra, Turkey. Yusef Aygul, Lindsay Falck. Photo Karen Falck.

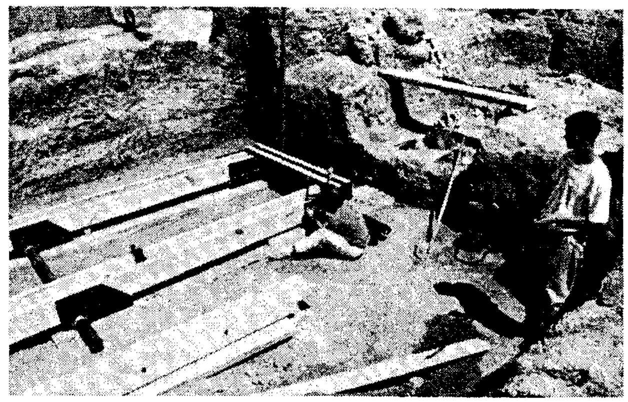

Fig. 5. On-site erection of Lifting rig ground beams. Caitlin Moore and Evan Kopelson. Photo Lindsay Falck.

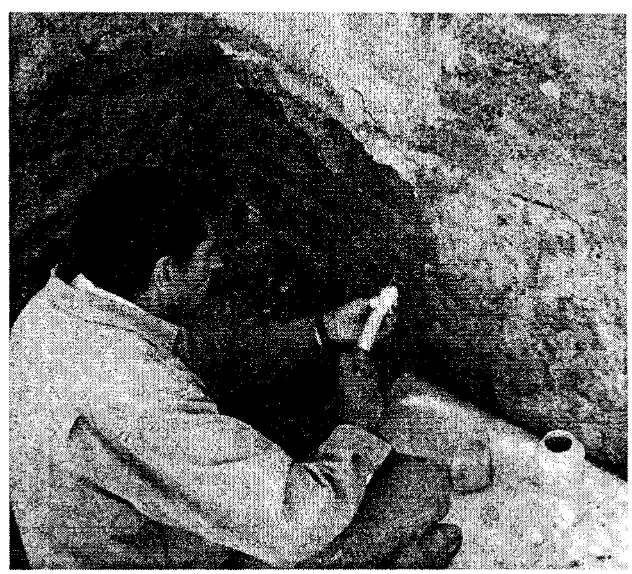

Fig. 6. Stabilization and consolidation of plastered wall surfaces. Frank Matero. Photo Lindsay Falck.

The stage had now been reached where the use of the vacuum extract system was essential for the insertion of the lifting spades at the base of the wall. The vacuum equipment had been purchased in Philadelphia for transport to Turkey, but British Airways could not be persuaded to carry any further overweight luggage, so it was not taken. Lindsay Falck returned to Ankara to try to buy or rent a suitable vacuum extract unit. When this proved impossible, it was decided to have the original unit sent from Philadelphia by express delivery. Customs documents were carefully prepared and delivered to Ankara Airport Customs officials. However, a 12-day delay in release ensued. This was a very serious delay, causing numerous airline flight re-bookings for Caitlin Moore and Lindsay Falck.

Insertion of Lifting Spades, and Application of Uplift Forces

With the lifting harness and wall support backing elements completed, the work of inserting the lifting spades was started. Slots of 150-mm width (6") and 25mm (1") height were cut into the base of the wall and the first, third and fifth steel lifting spades inserted. A pre-load uplift of an estimated 50% of the weight of the wall panel was applied by tightening the chain hoist supporting the lifting harness.

Cutting the spade-slots was extremely difficult in the very moist bottom layers of the wall. A special core drill of 25mm (1") stainless steel tube with hand cut teeth had to be made on site to do this work, the core drill being driven by a Milwaukee right angle electric drill. Each slot in the wall took approximately 3 hours to cut with this drill system and hand chisels.

Side Release Cuts

At this stage the left and right hand side-release cuts were made. This was done to prevent any lateral tear-cracking occurring across the side limits of the panel during later detachment-drilling phases.

The right hand side release-cut was made first with a coarse toothed 1.5 mm (1/16") wide carpenters handsaw, removing the narrow surplus edge of the existing wall as cutting proceeded. The left hand side release-cut was made with an 18 mm core drill, to obtain wall samples over the full height of the wall, so as to predict drilling conditions in a center-wall condition, in comparison to the more desiccated open edge on the right hand side.

Once the side release-cuts had been completed, the intermediate lifting spades, numbers 2,4 and 6 were inserted and the uplift force on the chain hoist of the lifting harness increased to the full 100 percent of the estimated weight of the wall panel.

Release Drilling at the Rear of the Wall Panel

The drill-rig frame was then bolted to the flange ends of the top-lifting beam. The first release drill-hole was then drilled down the open face of the right hand side edge of the panel. Being able to observe the cutting action of the drill as it passed down the length of the panel was of advantage as this was the first time the drilling system had been put to the test.

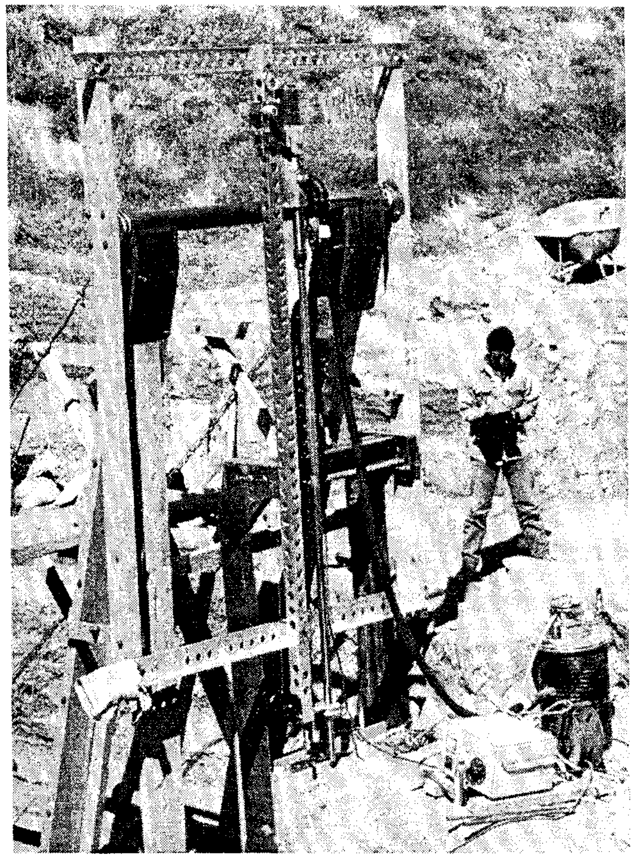

Fig. 7. Rig complete with drill frame and vacuum. Photo Lindsay Falck.

The drill cut a perfectly straight true hole. As described previously, the 50-mm (2") diameter Milwaukee tungsten core drill tip had been lost in a severe sandstonn during assembly of the drill at the site laboratory. As it was impossible to replace the drill bit at short notice it was decided to cut twelve cutting teeth into the bottom edge of the 45-mm (1 _") diameter drill tube. This meant that because the cutting diameter was only the width of the outside "set" of the teeth larger than the drill tube, the drill got additional guidance from the mud walls of the hole as it proceeded down the panel.

After completion of the first hole the tilt angle of the drill was adjusted very slightly and four further holes were drilled. At this stage, on the 9th of September, Lindsay Falck had to return to academic duties for the start of term at the University of Pennsylvania. Caitlin Moore had returned to the USA on the 4th September having also delayed her return in an effort to complete some of the more critical project phases.

It was hoped that Evan Kopelson and Connie Silver would be able to complete the release drilling and detach the wall panel. When this proved impractical it was decided that Lindsay Falck would return for three days to complete the project with Evan Kopelson and Connie Silver, later in September.

Fig. 8. Detached wall panel with carn-lock tubes. Photo Lindsay Falck.

Lindsay Falck returned to the dig site on the evening of 20 September. Work started immediately and the next day and the remaining release-drill holes were completed and the wall panel finally hoisted clear at 2:30 PM on 23 September. Drilling had been slow because of the very high moisture content of the bottom levels of the wall.

The cutting teeth of the drill had to be re-cut four times for the thirty five holes of approximately 1.4 m (60") length, the total wear on the high carbon stainless steel tube being 32mm (11/4").

The Locking Cam-Tube System

The locking cam-tube system for holding the wall panel hard against the lifting harness frame worked extremely well and was almost certainly the main reason for the absence of serious cracking in the wall panel during release drilling and detachment operations.

Detachment

The drilling sequence had been started from the right hand side of the panel. Each hole overlapped the previous hole by approximately 6 mm (1/4"). The overlap allowed the drilled-out material to fall clear, down to the bottom of the previously drilled holes where it could be easily extracted with a 25-mm (1") diameter tube on the end of the vacuum unit.

Once the drilling procedure had reached within 230 mm (9") of the left-hand side of the panel, the drill was demounted and turned around and drilling from the left side commenced. This was done to avoid shear fractures on the left side, at the panel edge.

It was unnecessary to drill the last two holes, connecting the left to the right side drill hole sequences because the 75 mm (3") remaining bridge piece of mud wall sheared vertically down the length of the panel, quite undramatically, achieving final detachment of the panel.

Hoisting Clear

Once loose, the wall panel was hoisted vertically by a small amount and the rig rolled back approximately 1.5 m to allow the harness and wall panel to be rotated by 90 degrees.

The harness and panel were then laid down horizontally so that the harness could be taken apart and the rest of the rig demounted.

Demounting the Rig

By 4:40 PM on Monday 23 September the lifting harness had been taken apart and work started on demounting the rig.

Demounting was completed by Lindsay Falck and Evan Kopelson assisted by Connie Silver at 2:40 am 24 September, just in time to meet departure arrangements for Lindsay Falck.

During the next days Evan Kopelson organized for the transport of all the drill and lifting rig components back to the site laboratory complex where they were packed under protective wrappings, and stored awaiting ongoing work phases in later dig seasons.

CONCLUSION

The project provided some unique learning experiences for the students, faculty and others involved. This learning carried through into all phases of the project from the first design ideas to the final demounting of the rig after the successful removal of the first wall-panel. The team had to constantly improvise new solutions to unforeseen problems in both the design and operation of the rig and of back-up strategies to offset possible problems in areas of transport logistics, material supply, on-site communication and chance hazards such as dust, rain and lightning storms. A wide range of non-conventional communication techniques was developed by team members in Turkey, where the real potentials of Agricultural Technology and the extremely high levels of skill and generosity of the Turkish work-team were discovered. To the over one hundred contributors to the project, a huge vote of thanks for wonderful help and co-operation and to Karen Falck particularly, very inadequate personal thanks.