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Treatment, Conservation and Restoration of Mudbrick Structures

Mathilde Gelin

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Mathilde Gelin. Treatment, Conservation and Restoration of Mudbrick Structures. Laïla Nehmé, Daifallah al-Talhi, François Villeneuve. Hegra 1-Report on the First Excavation Season at Madâ'in Sâlih-2008 Saudi Arabia, , pp.28-46, 2010, Hegra 1-Report on the First Excavation Season at Madâ'in Sâlih-2008 Saudi Arabia, 978-603-8022-31-3. <hal-03026287>

HAL Id: hal-03026287

<https://hal.science/hal-03026287v1>

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REPORT

REPORT

on the **First Excavation Season** at **MADÂ'IN SÂLIH**

2008  SAUDI ARABIA



First Excavation Season at **MADÂ'IN SÂLIH**



Prepared under the supervision
of **Laila Nehmé, Daifallah al-Talhi**
and **François Villeneuve**



SAUDI COMMISSION FOR TOURISM AND ANTIQUITIES

HEGRA I

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PREPARED UNDER THE SUPERVISION OF

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RIYADH

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Fig. 1. Map showing the location of the site.



Fig. 2. Distribution of the monuments and location of the various excavation areas.

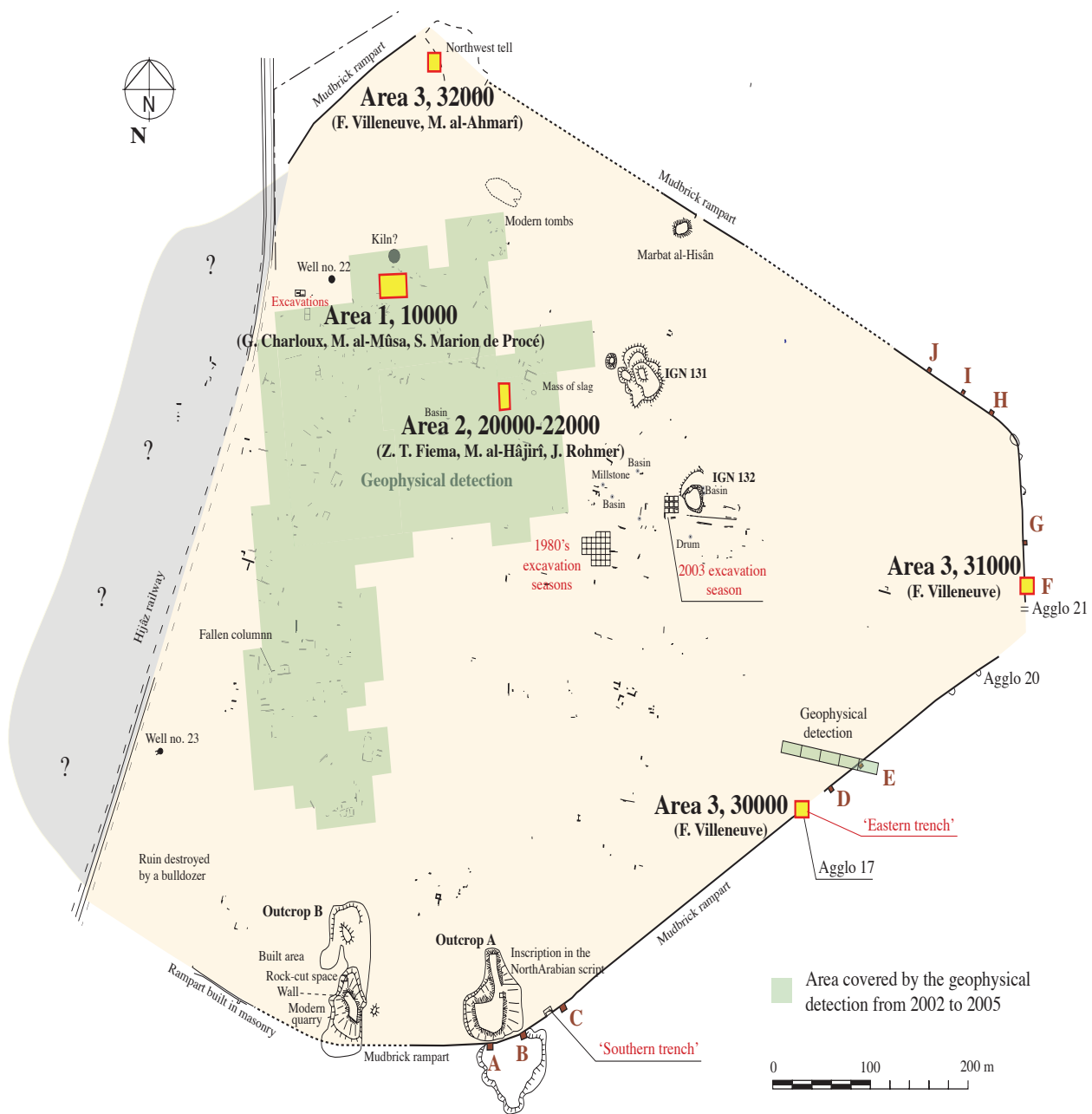


Fig. 3. Plan of the residential area and location of three of the excavation areas.

Treatment, Conservation and Restoration of Mudbrick Structures

Mathilde Gelin (CNRS, UMR 7041)

Treatment, Conservation and Restoration of Mudbrick Structures

Recommendations for the preservation of mud architecture

Generally, mud resists very poorly to bad weather (particularly to humidity) and to time. That is why it is recommended that masonry should be protected at the end of each excavation season before degradation begins. For reasons of compatibility with the ancient materials, mud architecture should be conserved with mud and, even if the mud used is of good quality, it has to be replaced regularly since bad weather also affects this protection. Excavated structures, therefore, need constant maintenance over the years. It is also better to plan some measures to prevent water from stagnating at the bottom of the walls, even if the rainy season is short.

Over the last few years, methods of conservation and restoration of mud constructions have been evolving rapidly. The soil to be used must be carefully chosen following physical and chemical analyses and, if necessary, stabilized in order to become more resistant. Natural and chemical products can be used for this in strictly defined proportions. Some architects are specializing in these studies, as well as the CRAterre (*Centre de recherche sur l'architecture en terre*, in Grenoble, France). PhD theses are currently being submitted on soil stabilization using organic, mineral and chemical elements. In order to ensure the best results, it is strongly recommended that specialists are contacted. The followings recommendations are general and can be modified according to the physical and chemical qualities of the soil chosen.

■ **Choice of soil**

The soil chosen should contain as few organic elements and salts as possible because these can quickly affect the quality of the soil as well as the remains with which it will come in contact. Therefore, if physical and chemical analyses are not possible, it is strongly advised to avoid using the backfill from the excavations.

■ **Distinction between the consolidation and the ruins**

The new restorations must be distinguishable from the original remains. For example, one can use modern fibres (such as the “plastic” fibres used as a framework in modern cement buildings) to replace or reinforce the straw in the mudbricks, or add some to plasters and mortars.

■ **Mud walls**

Ideally, the tops of the walls should be protected with a layer of new mudbricks or a thick layer of soil. The faces of the walls should also be protected with mud plaster. If the wall is very damaged, the holes and cracks should be filled with mud, possibly mixed with small stones (but the stones should not be visible). This technique was already used in antiquity, as was observed in excavated ruins, in Syria for example.

■ **Stone walls cemented with mud**

Originally, these walls were covered with plaster and the stones were rarely visible. Therefore, it is recommended that the same procedure is followed as for mud walls. However, in order to achieve a better presentation, it is possible to protect only the joints with mud and this protection should be renewed frequently. Of course, the conservation of the stones themselves, especially if they are of soft sandstone, must also be considered.

Recommendations for the choice of soil to be used to protect the walls of the residential area

In the settlement of Hegra, the walls exposed during the excavations stand on foundations of sandstone rubble assembled with earth mortar.¹ A few foundations are made of dressed blocks also assembled with earth mortar. The superstructures of the walls are always made of mud. In the work done so far, only mudbrick has been found, but pisé cannot be excluded and future excavations will show whether or not it was used.

The project wished to protect the excavated remains, particularly from bad weather. The material chosen for this protection is soil because of its compatibility with the original materials. It was therefore necessary to determine which soil was best suited for the task.

We searched² in the immediate vicinity of the site in order to avoid issues of long and difficult transport. This approach also allowed to realize how close to the site were the areas which might have been used as earth quarries by the ancient builders.

The areas were selected on the basis of the qualities of the soil and the ease of its exploitation. All the soils which contained salt, the presence of which was gauged by tasting it, were excluded.

The soils which were sampled, shown on **fig. 1**, came from the following places:

1. the large wadi to the southwest of the site, clearly visible on the satellite image. Soil from the surrounding area accumulated with the flow of rainwater in the wadi;
 2. west of the site, at the bottom of a rocky escarpment, a quarry currently in use, with numerous bulldozer tracks around it;
 3. northwest of the site, in an area which receives the accumulations washed in by rainwater;
 4. in the immediate vicinity (to the west) of the main entrance to the site, a quarry still in use today.
- A potential sand quarry was also located. If necessary, sand can indeed be added to the soil or placed in contact with the ancient walls for other types of protection.

■ Tests

Several tests were carried out on the samples. The first set aimed at testing the mechanical resistance of the soil (hardness, resistance to traction and pressure), its withdrawal from and its adherence to the local stone. The second set of tests evaluated the grain size of the mineral elements and the proportion of organic matter contained.

First set of tests

The soil was mixed with water until a thick paste was obtained, the same consistency as needed for the manufacture of mudbricks. The mixture was then put onto dampened stones and left to dry, forming “cakes” of earth, exposed to the sun and wind. For each soil, the first cake was made simply of soil and water (= N for neutral) and the second was made of the same mixture with the addition of some chopped straw (= S).

1. With the exception of the rampart, which may be made of mudbrick laid straight on the ground.
2. On the 28th January 2008, D. al-Talhi, M. al-Mutlaq and M. Gelin, and on the 29th, D. al-Talhi, Z. Muhammad ‘Awda and M. Gelin.

Zidane Muhammad ‘Awda (freelance conservator in charge of the conservation of the citadel and old town of al-‘Ulâ) suggested the addition of wood glue which, according to him, produces better adherence. Some tests were carried out using this material, with (= WGS) and without straw (= WG).

It should be noted that, due to the weathering of the sandstone on which the tests were carried out, a thin layer of sand detached itself from the surface of the rock and this affected slightly the adherence of the soils on it. However, since some of the protection will need to be carried out on sandstone, the tests are still of value.

RESULTS

- 1N: when mixed, the soil is very sticky, quickly adhering to the hand. After drying, it is very hard, compact, without cracks. The average adherence is good. It breaks after a certain amount of pressure is applied (**fig. 2**).
- 1S: same qualities as 1N but it breaks less quickly.
- 1WG and 1WGS: numerous cracks but they adhere perhaps slightly better to the rock.
- 2N: after drying, it becomes hard and it has a medium adherence to the rock. It shows cracks and it breaks easily (**fig. 3**).
- 2S: it is hard, it holds well and it has a medium adherence. It breaks less easily.
- 3N: it is hard and breakable. It shows cracks and it has a weak adherence to the rock.
- 3S: it is hard, with a few cracks only, it holds well and it has a very good adherence (it is the only sample which did not unstick from the rock) (**fig. 4**).
- 4N: it is hard, with cracks, and it has a good adherence to the rock.
- 4S: it is hard without cracks.

Second set of tests

Soil from each location, in equal amounts (in this case three spoons), was put in a glass (the glass should be straight sided and flat bottomed, which was not quite the case here) and the glass was filled with water up to the top. The contents were carefully mixed and left to stand so that the different fractions could settle.

The mineral fractions settle, according to their size and weight, in decreasing order from the bottom to the top. Thus, the coarsest materials (sands) settle at the bottom of the glass. The other materials (fine sands, silts, clays) settle in turn, the finest remaining at the top. Organic matters stay in suspension on the surface. Foam is usually indicative of the presence of organic elements.

<i>AFNOR standard</i>	<i>Grain size in mm</i>
Clays	≤ 0.002
Fine silts	0.002-0.02
Silts	0.02-0.06
Fine sands	0.06-0.2
Coarse sands	0.2-2
Gravels	2-20
Stones	20-200

*Grain size of the minerals
in the soil,
AFNOR standard*

The thickness of each layer was measured (**figs 5, 6, 7**). The following calculations of the proportions are relative, because the materials varied from one sample to the next and from one test to the next. We will not go into details here but the best comparisons were between soils which displayed the most similarities: soils 1 and 3 on the one hand, and 2 and 4 on the other.

RESULTS

1: almost no foam. A little organic matter in suspension. No distinguishable water line, the finest materials (clays) remain in an evenly distributed suspension. The sands, which are rather fine, and the silts are at the bottom of the glass.

In terms of proportions, soil no. 1 has about 36 % “coarse” material (meaning in this case fine sands and silts), 61 % very fine material (clays in suspension) and about 3 % organic material, estimated on the basis of the volume of the foam (which means that the amount is overestimated).

2: a little foam. Very little organic matter (a few wisps of straw). The water line is clearly defined (meaning there is very little clay in suspension), and the water is fairly clear (meaning there is very little organic matter). A layer of sands (coarse and fine) and a layer of finer material (undifferentiated silts and clays) are relatively easy to distinguish.

Proportions: about 66 % sands, 24 % fine material (silts and clays) and 10 % organic matter.

3: presence of foam and some material visible to the naked eye. No water line, the clays remain in suspension. Very little coarse sand.

Proportions: 44 % “coarse” material (sands and silts), 49 % fine materials (clays in suspension) and about 7 % organic matter.

4: a lot of foam and material in suspension, cloudy water. Water line well marked. Large proportion of sands.

Proportions: about 50 % coarse materials, 25 % fine materials and 25 % organic matter.

■ Conclusions

With the exception of soil no. 4, which contains the largest quantity of organic matter and which makes it unusable, most of the soils can be used for reconstruction.

Soil no. 3 seems the best recommended, with the addition of straw, for the manufacture of mudbricks as well as for creating a solid protective layer on the tops of the walls. It has good mechanical resistance and it contains significant proportions of clays and sands.

Soil no. 1 seems best adapted, without straw, to use as protection against damp because it contains the highest proportion of clays that swell and thus reject water. It will need to be as compacted as possible, and smoothed (a wet hand is sufficient). If a thick layer is required, it will be necessary to apply it in several layers because it is very clayey and contains a minimal amount of tempering agent, meaning that it is liable to crack easily. Such cracks are not a problem if they are spread out and covered over from one layer to the next.

Finally, soil no. 2 lacks clays, which makes it inflexible and therefore too breakable.

In the light of these results, soils no. 1 and 3 were selected. However, because of the high viscosity of soil no. 1, hands and tools that will come in contact with it should be thoroughly wetted in order to be able to use it without too much difficulty.

Suggestions for the presentation of the remains in Jabal Ithlib

The *triclinium* excavated at the mouth of the defile leading into the Jabal Ithlib from the Dîwân, comprises three walls forming U-shape benches, built directly on bedrock at the foot of the slope (see L. Nehmé's report in this volume). Such a location exposes them to the heavy flow of rainwater and the accumulation of sand. This has resulted in the disappearance of some parts of the *triclinium* benches due to the dislocation and movement of some of the masonry blocks.

The whole structure is very low (a maximum of 50 cm) and consists of dressed facing blocks built on the ground. The wall has a rubble and earth core.

The following suggestions were made in the field and in no way replace the opinion and expertise of a specialist.

■ Protection of the wall footings

Placing a layer of soil no. 1, the most water-tight, forming a small slope against the foot of the walls is recommended. This should deflect the flow of rainwater to prevent its infiltration into and under the walls, as well as to direct it to the lowest point of the slope.

In the same way, putting gravel against the outside face of the walls, before covering them with sand, will allow better drainage and a better channelling of the water.

During the work, however, gravel was not put in place and soil no. 1, felt to be too viscous by workmen who did not understand its waterproofing role, was often mixed with sand.

■ Restoration of the wall face

It is recommended that the original, displaced, blocks be put back in place using the method as used in antiquity, which can be seen in the best preserved wall: a setting course, made of small flat stones and mud mortar, compensates for the slope of the bedrock and allows the facing stones to sit horizontally. The tops of these blocks also form a horizontal level. Soil no. 3 is recommended for the mortar.

■ Restoration of the wall fill

It is recommended that some rubble be put back in place. Soil no. 3 can be used for this. The top should be covered by a thick layer of soil no. 1, to prevent as much as possible infiltration of water into the wall.

Originally, we had intended to put gravel at the bottom of the fill to ensure good air circulation; however, the risk of movement of the wall made it unsafe to do so.

After the completion of the work, it has become clear that the thick, uniform layer of earth covering the fill fired the curiosity of some visitors who attempted to remove parts of it after the team's departure. Additionally, from an aesthetic point of view, this solution does not seem the most pleasing (**fig. 8**). That is why we suggest leaving some pieces of rubble sticking out of this layer, but not too many in order to preserve its waterproofing function. In this way, seeing what lies below the layer of earth would assuage the curiosity of visitors and the presentation of the wall fill would be less monotonous.

Suggestions for the temporary display of the remains uncovered in the 2008 season

The following recommendations are for conservation between two excavation seasons (layers of sand) and for several years (thick layers of mud mortar), with the aim of providing protection against the rain.

■ **For all trenches**

- Make an earth levee (backfill from the excavations) around the trenches that are on or at the bottom of a slope in order to direct the flow of rainwater away from the excavations. For area 1 (G. Charloux), an extra levee is needed to the southwest, at the top of the small wadi that opens into the southwestern corner of the area (a line of stones covered with backfill, well trampled down and possibly wetted).
- Make a small earth levee (backfill well packed down with shovels) at the base of the walls, in order to keep rainwater flow away.
- Protect the tops of mudbrick walls (except in the soundings of Z. T. Fiema, south of area 2) with a thin layer of sand (which will prevent the earth from sticking to the ancient mudbricks) then with a thick layer of soil. This soil (no. 3) should be mixed with water and applied either in a 5 cm or a 10 cm layer. In the latter case, it should be applied in two stages, allowing the first layer to dry a little.
- Stone walls should be protected in the same way, if possible. In cases where there is not enough time, or not enough soil, a thick layer of sand (at least 10 cm) should be sufficient until the following year.
- For all the levels where excavation ceased, as well as for the mudbricks in Z. T. Fiema's trench, a layer of sand of at least 10 cm is sufficient.

■ **G. Charloux' trench (area 1)**

- Fill the deep soundings.
- Protect the jambs/lintels/thresholds with a thick layer of sand. It might even be better to put a canvas first.

■ **Z. T. Fiema's trench (area 2 south)**

- Protect the channels with a thick layer of sand. It might even be better to put a canvas first.
- Protect the oven with canvas (only one layer, so the sack should be unfolded) and cover with sand.

■ **J. Rohmer's trench (area 2 north)**

- Hole in the paving: to avoid rainwater stagnating in it and the draining of the pavement, fill the hole with sand bags that must protrude above the level of the paving. Cover with a thick sheet of plastic, weighed down by a plank, which will direct the rainwater onto the pavement and not to the foot of the wall or into the hole to stagnate.
- Cover the pavement with a thick layer of sand.

Suggestions for the conservation and the presentation of mud architecture from the earlier excavations in the residential area

The excavations undertaken between 1986 and 1990 by D. al-Talhi in the residential area (**figs 13 and 29**) uncovered walls which belong to two main phases of occupation. Since then, these walls have been exposed to the elements and they are now damaged. Most were built of sandstone blocks bonded with mud mortar and the majority are, in fact, the foundations of walls the superstructure of

which were probably made of mudbricks. Some walls, entirely built of mud, belonging to the first phase of occupation,³ are now almost invisible. Some of the mudbrick walls are severely eroded. Before a decision concerning the conservation and presentation of the excavations can be made, it is important to choose which of the two phases of occupation is to be presented. Indeed, it is extremely difficult to present the walls from both phases at the same time, since those from phase 2 are at a higher level than those of phase 1. Therefore, choosing to present the phase 1 walls would expose those of phase 2 to the risk of being undercut. Most of the phase 2 rooms do not contain remains from the first phase and when they do, these remains are fragmentary and are not always associated with other walls (see, for example **fig. 13**, the wall of phase 1 in room no. 5, north of square I20). Moreover, it should be noted that a succession of walls belonging to several periods prevents the visitor from understanding the architectural units as a whole.

These remarks explain why we suggest that most of the rooms should be filled up to the base of the walls of phase 2. This is the only way the remains of phase 1 can be protected. However, since the remains from the first phase are more concentrated in the southwestern part of the excavations, this area could, perhaps, be chosen for the presentation of the remains of the first phase.

■ Problems observed with the walls (**fig. 9**)

- they are destabilized by digging under the level of their foundation (**fig. 10**);
- undercutting of the walls is caused by rainwater runoff and by the fact that water stagnates at the foot of the walls;
- the mud mortar between the stones is being eroded away, which causes the loosening of the stones;
- the top stones are often damaged (exfoliation, cracking, turning into powder) (**fig. 11**);
- severe erosion of the mud walls (**fig. 12**).

■ Problems of presentation (**fig. 13**):

- the baulks, which can be confused with walls, make it very difficult to understand the exposed remains and the architectural units they form (**fig. 14**);
- general understanding is hampered by the existence of two building phases (**fig. 15**).

■ Suggestions (**fig. 16**):

- fill the soundings at least up to the level of the base of the walls (in this case, the backfill from previous excavations can be used, **fig. 17**). A chronological indicator (such as a coin) should be thrown into the sounding before filling;
- level the fill in order to direct rainwater towards the centre of the room/trench, so as to take it as far away as possible from the walls. A small slope with well trampled earth should be made at the foot of the walls, and there should be a slight depression in the centre of the room/trench;
- lower the level of the baulks down to the foot of the walls (**fig. 18**);
- for holes *under* the walls: wet them and fill them with small stones combined with soil no. 3 mixed with straw and a chronological indicator (such as plastic fibres). The mortar should not be too wet, otherwise it will not stick properly (**figs 19-25**);
- for holes *in* the walls: if the hole is big, follow the same recommendations as above; if the hole is small, fill it with mud mortar only;

3. In their present state, without further cleaning, it is not possible to determine whether the walls are of mudbrick or pisé.

- for the faces and the tops of the walls: clean and wet the joints, then fill them with soil no. 1 mixed with a chronological indicator such as gravel (note that too much gravel would diminish the sticking qualities of the clay) and then polish the surface (**figs 26-27**).

■ **Trial conservation and presentation: room 5 (figs 28-34)**

Room 5 belongs to phase 2 (**figs 13, 28-29**), and was chosen for the trial conservation and presentation because, on the one hand it is a small room (around 3.75 x 2.50 m), and on the other hand it has a phase 1 wall in its centre. The aim was to attempt the conservation of the phase 2 walls, the foundations of which are at a higher level, whilst also presenting the earlier phase, founded at a lower level.

The following treatment was applied to the different elements of this architectural unit:

- the baulks which were in, or near, the room and which confused the visual interpretation, were removed to expose the various walls;

- the trenches were filled up to the second course of the wall of phase 1, after placing chronological markers at the bottom (a Pakistani and a 5 euro cent coin). A slope made of small stones and mud mortar (soil no. 3 with straw and a marker) was placed under the walls of phase 2 up to their base, in order to reinforce the earth on which they stand and to keep the rainwater away. The area was generally levelled again in order to keep water away from the base of the walls. After cleaning, the joints of the walls were filled with mud mortar (soil no. 1 with a marker);

- a hole under the east face of the east wall was filled with small stones and mud mortar (soil no. 3, straw and small pieces of polystyrene). The joints of the faces and top of the wall were filled with mud mortar (soil no. 1 with a little chamotte, that is burnt clay). The soundings at the foot of this wall were filled (two 5 euro cent coins were used as markers), and levelled.

This test provides a view of the complete phase 2 room and of the earlier wall, as well as placing the room in the context of its neighbouring walls. The walls were consolidated and preserved, and levelling was carried out to keep water away. In the future, the strength of the soils and the general appearance of the room will give some indications as to what should be done to preserve all the walls from these older excavations.

■ **Suggestions**

In order to ensure a better conservation of the tops of stone walls, three solutions are suggested:

- cover the top with a thick layer of soil no. 1 (at least 10 cm, in two layers), on which the joints between the mudbricks can be incised;

- build on one course of stones bonded with soil;

- build on one course of stone foundation with one or two courses of mudbricks above to show what the superstructure of the wall might have looked like originally.

The two last suggestions are appropriate for the presentation of the remains, the last being the closest to the original aspect of the buildings.

In all cases, the newly built parts of the walls should always be slightly stepped back from the face of the original wall in order to distinguish visually the old from the new. ■

Figures



Fig. 1. Google Earth image showing the location of the soil quarries.



Fig. 2. Mechanical resistance test on soil no. 1, without straw on the left, with straw on the right.



Fig. 3. Mechanical resistance test on soil no. 2, without straw on the left, with straw on the right.



Fig. 4. Mechanical resistance test on soil no. 3, without straw on the left, with straw on the right.

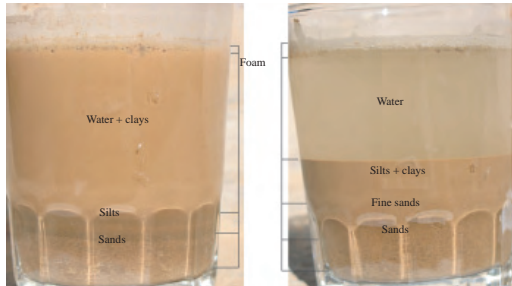


Fig. 5. Grain size test. From left to right: soils no. 1 and 2.



Fig. 6. Grain size test. Soil no. 3.



Fig. 7. Grain size test. Soil no. 4.



Fig. 8. Restoration of one of the benches belonging to the *triclinium* in Jabal Ithlib.

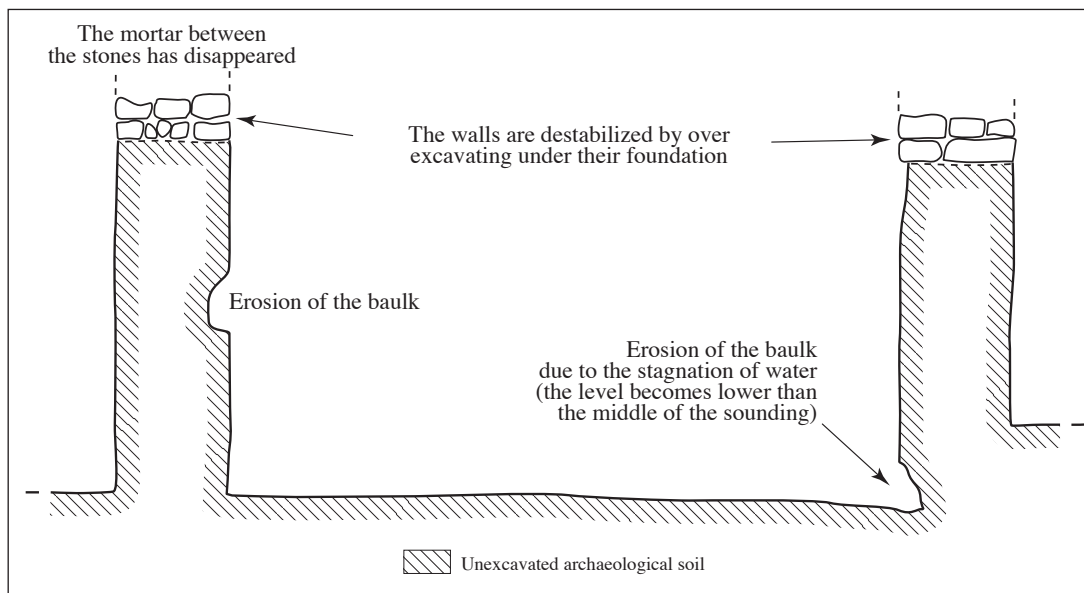


Fig. 9. Sketch showing the main problems which have been observed on the walls due to bad weather and undermining under the structures. Drawing M. Gelin.



Fig. 10. Undermining below the foundation of the walls leads to their weakening and even to their collapse.



Fig. 11. Top of a sandstone wall foundation. The stones are loosened and broken.



Fig. 12. Erosion of a mudbrick wall. Note the vegetation and the traces left by the stagnation of water.

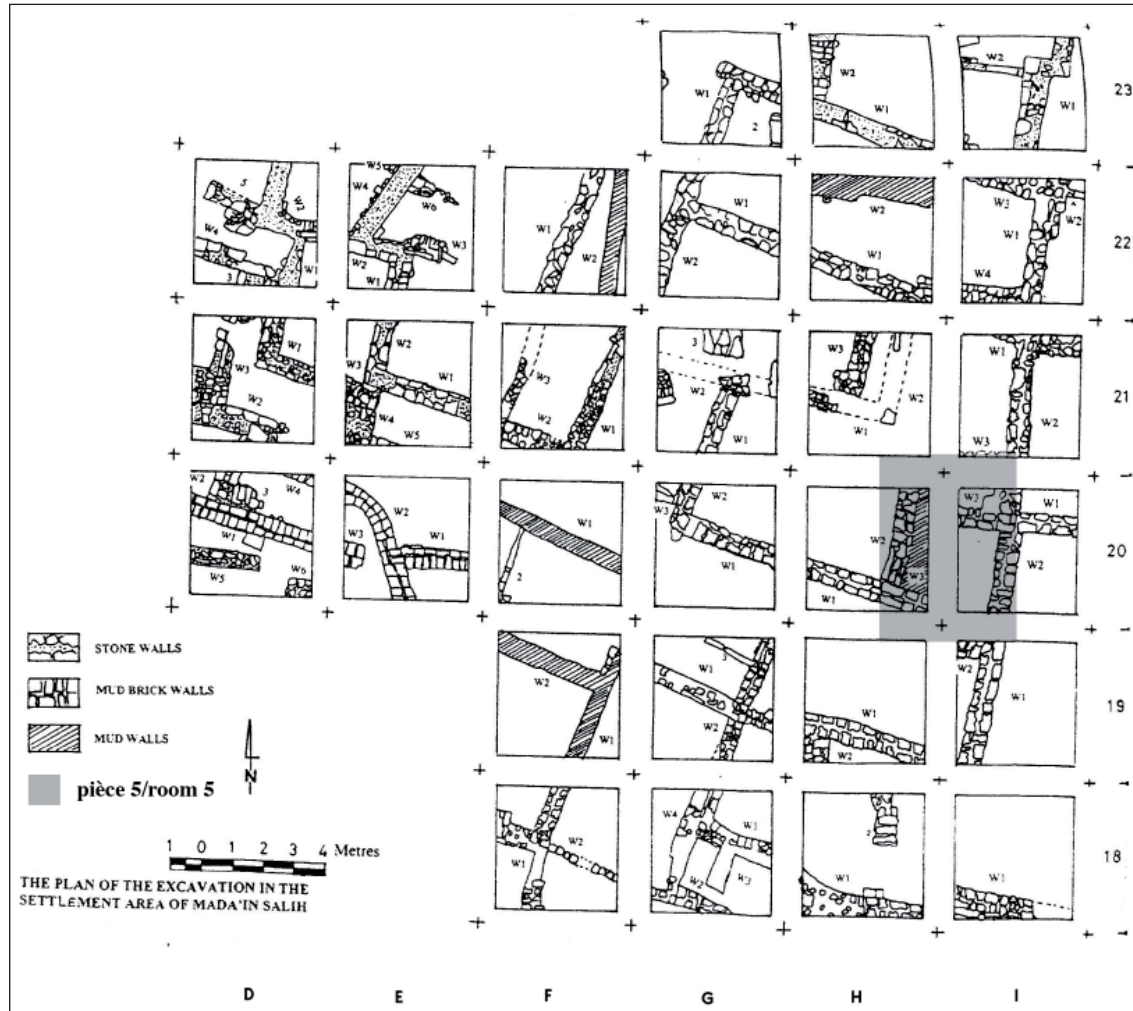


Fig. 13. This plan demonstrates how the baulks hamper the understanding of the excavated structures: it shows the walls of both phases and the baulks. Plan from D. al-Talhi, *Mada'in Salih, a Nabataean Town in North West Arabia: Analysis and Interpretation of the Excavation 1986-1990*, PhD Thesis, Department of Archaeology, University of Southampton, 2000, p. 233, fig. 32.



Fig. 14. In this area, the distinction between the baulks and the mudbrick walls is almost impossible.



Fig. 15. Remains of the first building phase, not bonded together and severely weakened.

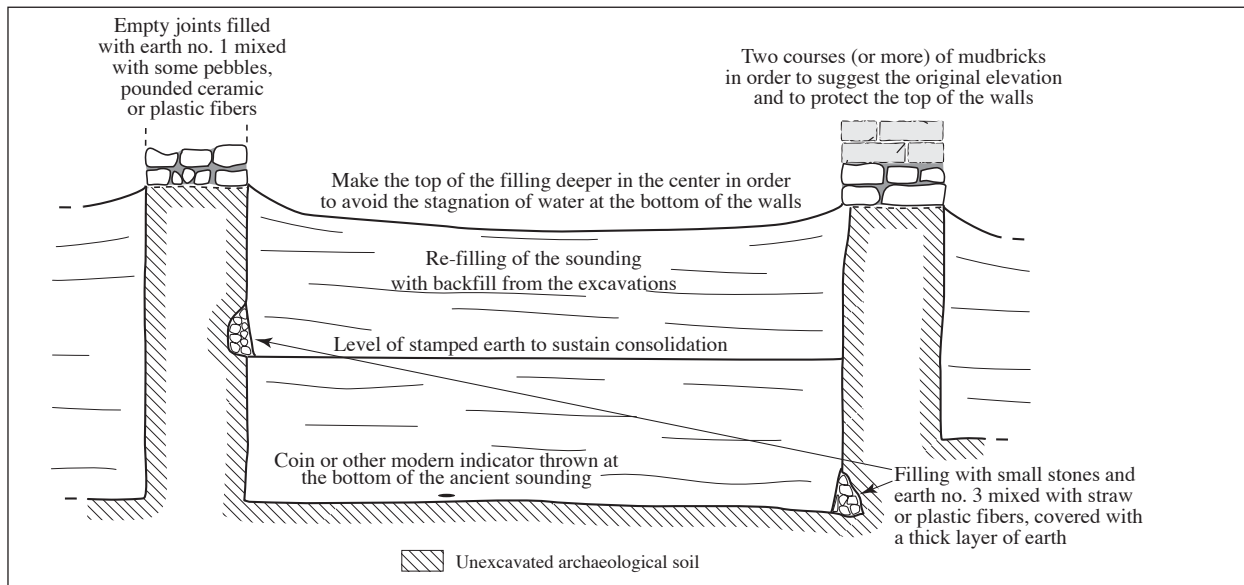


Fig. 16. Suggestions for the stabilization of the walls. Drawing M. Gelin.



Fig. 17. Refilling of a sounding.



Fig. 18. Removal of a baulk down to the level of the base of the walls.



Fig. 19. Addition of a modern indicator in the soil (here polystyrene).



Fig. 20. Mud (for building) ready to use.

Figs 21 to 25

Consolidation under the base of an undermined wall: in a previously cleaned and wetted area, placing of mud followed by small stones covered with earth.





Fig. 26. The joints of the walls have been filled with mortar and the base, which is to be exposed, is reinforced by a bench made of small stones and mud.



Fig. 27. The joints of the top of the wall have been filled with mortar. Some of the missing parts have been rebuilt with the same materials as those used in antiquity.

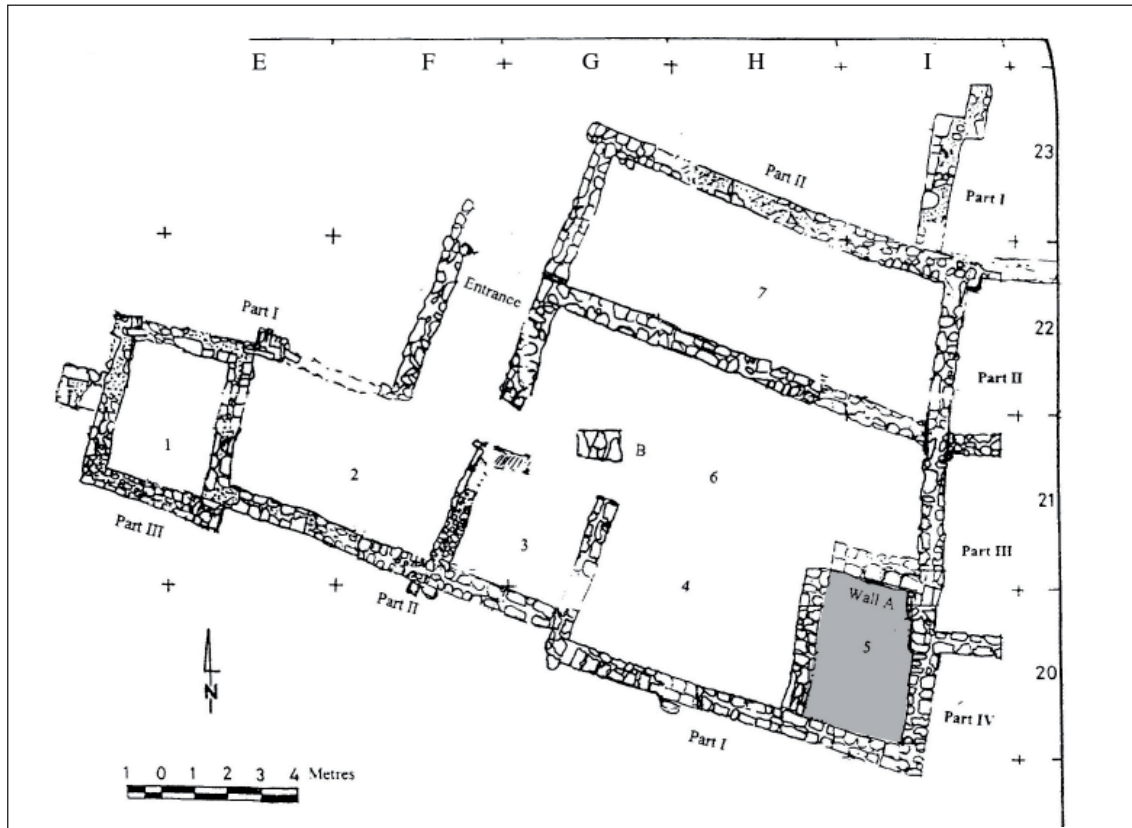


Fig. 28. Residential unit in the old excavations, showing the remains belonging to phase 2. Room 5 is in the southeast corner. Plan from D. al-Talhi (cf. fig. 13), p. 234, fig. 33.



Fig. 29. Aerial view of the old excavations after the work undertaken in 2008. Room 5 is in the centre of the photograph, on the right.

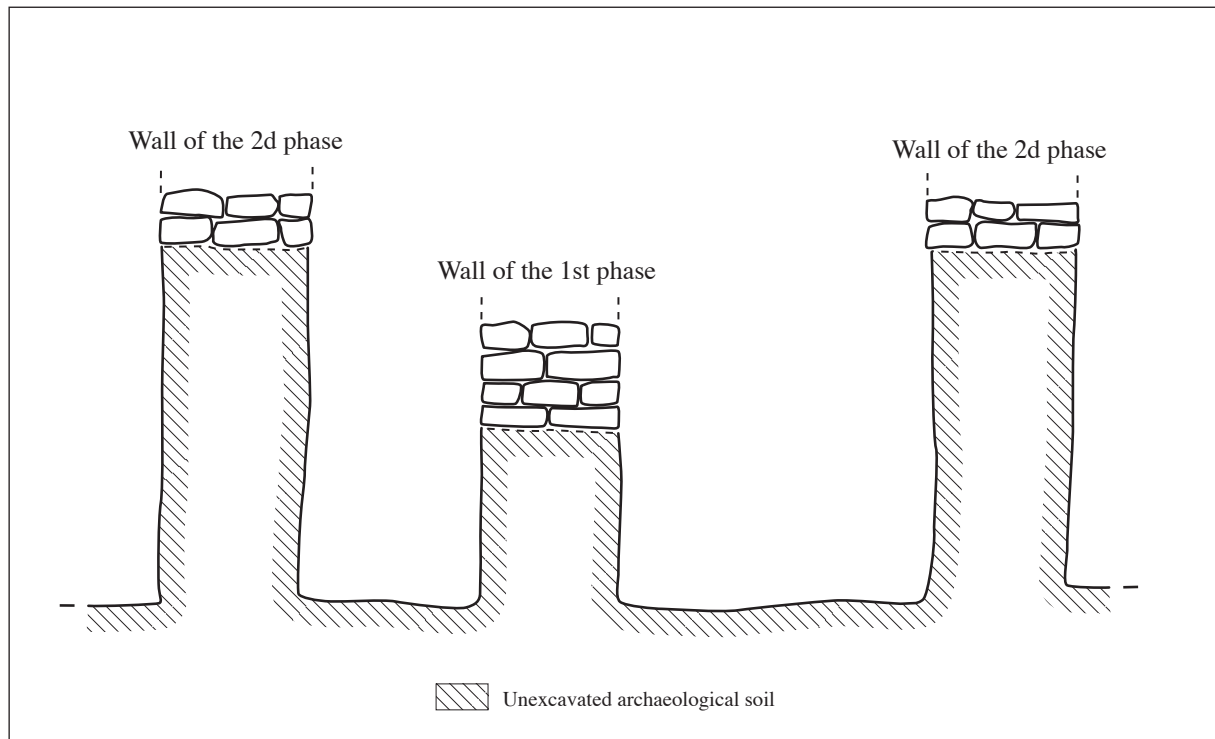


Fig. 30. Sketch showing the presentation of the walls belonging to the two building phases. Drawing M. Gelin.

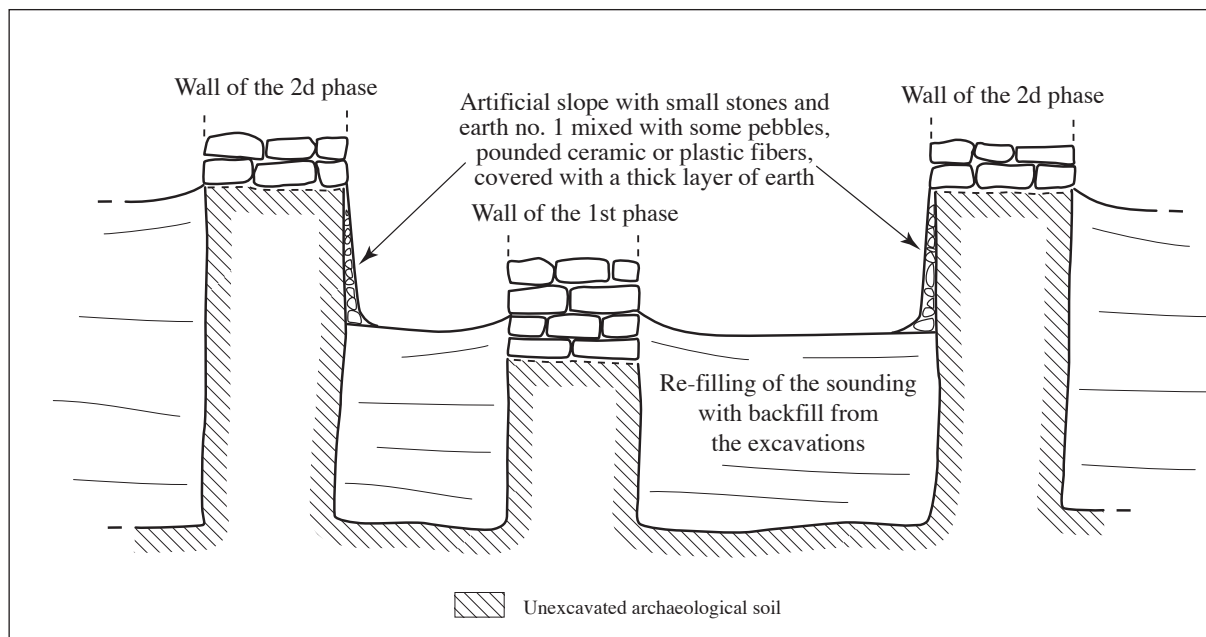


Fig. 31. Suggestions of what should be done to present the two phases of occupation, as done in room 5. Drawing M. Gelin.



Fig. 32. Room 5, east wall, undermined wall.



Fig. 33. Room 5, baulk in the middle of the room which lies partly over a phase 1 wall.



Fig. 34. General view of room 5, consolidated for presentation.



Madâ'in Sâlih, ancient Hegra of the Nabataeans, is one of the most impressive sites in the Middle East, and in 2008 was the first site in Saudi Arabia to be inscribed on UNESCO's World Heritage List. It has been called the 'southern capital' of the Nabataean kingdom which stretched from Syria to northern Arabia and which was famous for its sophisticated water-catchment techniques, far-flung commercial network, the beauty of its architecture and the delicacy of its pottery.

Madâ'in Sâlih has long been famous for its monumental tombs but they have never been systematically investigated, and nothing is known of the city itself which is hidden by the desert sands. Now, for the first time, a Saudi-French archaeological project is investigating every aspect of the site. After five years of archaeological, epigraphic, geophysical, and hydrological survey of all parts of the site, this book presents the full report of the first season of excavations (2008): in the residential area, the city wall, the area of *tumuli*, in the monumental tombs, and among the religious monuments of Jabal Ithlib. It includes not only reports on the excavations, but preliminary studies of the pottery, archaeobotanical remains, and proposals for the conservation and the presentation of the mudbrick architecture. The results of these excavations are of the utmost importance for our understanding of the ancient history of Arabia and its relationship with the Hellenised Near East.