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ΘΕΣΣΑΛΟΝΙΚΗ - THESSALONIKI 2005

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Introduction

Zeugma is the name given to two cities, Apamea and Seleucia, founded by Seleucus I (312-281 BC) on opposite banks of the Euphrates in southeastern Anatolia, Turkey. The two cities were linked by a bridge for which they were named – "zeugma" meaning "bridge" in Greek.

In the first century BC, the two cities came under Roman control. The IV legion was posted in this region to control the bridge – the only stable crossing of the Euphrates for hundreds of kilometers. For 200 years, the cities were an important trade link between the Roman and Parthian empires. At its peak, Zeugma had between 50,000 and 75,000 inhabitants and covered more than 2000 hectares on the west bank. As the power of the Roman Empire waned in the 3rd century AD, the city was sacked and burned (AD 252) by the Sassanids.

The site was identified in the 1970s by the German archaeologist Jörg Wagner. Research excavation, conducted by David Kennedy of the University of Western Australia, Catherine Abadie-Reynal, Professor at the University of La Rochelle, and the Turkish Ministry of Culture - Gaziantep Museum, took place during the 1980s and 1990s.

During the same period, Zeugma was affected by a major regional hydroelectric project, which involved the construction of various dams. One of these, the Birecik dam and its reservoir, would submerge 30% of the surface of the ancient city during the summer of 2000. The flooding was scheduled to take place in two phases, the first (June 2000) would submerge the so-called "Area A"; the second (end of October 2000) would submerge the so-called "Area B" (fig. 1).

In May 2000, partly due to exceptional finds of movable objects and of two villas richly decorated with frescoes and mosaics, the efforts of a local newspaper editor in Gaziantep[1] manage to attract the attention of the international press, and an appeal for Zeugma rapidly circles the globe. The Packard Humanities Institute (PHI), based in California, responds to the appeal, immediately offering the economic and human resources to organize and co-ordinate a rapid action plan with the Turkish Ministry of Culture.

In a matter of days, after Area A had already been completely inundated, an operative structure was set up with support from the PHI and directed by the Turkish Ministry of Culture. It had three objectives: emergency archaeological investigation of Area B; conservation during excavation of Area B and of finds from previous campaigns at Zeugma; and publication of the scientific results. The operative structure included various entities:

- The Great Anatolia Project (GAP) to co-ordinate logistics;
- Oxford Archaeology Unit (OAU)[2] to co-ordinate the archaeological investigation;
- Centro di Conservazione Archeologica of Rome (CCA) to co-ordinate conservation.

The situation in June 2000

After long years of work, the dam is ready to stem the flow of the Euphrates. From May to October 2000, the water level begins to rise in the new basin at a rate of 20 cm a day, inexorably, day after day; The economic life of the dam is considered to be 100 years (GAP 2001: 29), after which time the lake will be so clogged with debris that the power station will be unable to function; Among the vast areas destined to be submerged are the entire city of Apamea, some 30% of the rest of Zeugma and Belkis, the inhabited village nearby. In Zeugma, the situation in June 2000 is as follows:

- 25% of the city will be entirely submerged (Area A);
- 15% will be in a fluctuating water zone (Area B), with continuous variations in water level subject to the workings of the dam;
- the remaining 70% of the city will be above the water (Area C);
- Area A was excavated by the Ministry of Culture of Turkey-Museum of

1. Mr. Aykut Tuzcu, editor of Sabah, the Gaziantep daily paper, whose appeal was taken up by the New York Times.

2. The excavation was done by the Oxford Unit, the Gaziantep Museum and the University of Nantes.

Gaziantep, University of Western Australia, University of Nantes. During two campaigns some 4000 movable objects, about 100 architectural elements, 700 m^2 of mosaics, and 250 m^2 of wall paintings were detached and removed from the site. Everything, without any selection criteria, was systematically detached from its original location;

• the structures still *in situ*, the trenches and the stratigraphy that had not been disturbed during excavation and detachment operations were sent underwater without any protection (fig. 2).

As for the detachment of the mosaics, in the interventions prior to May 2000:

- it was performed with very poor documentation, numbering or written reports;
- it was not performed by professional personnel, but by museum workmen and guards or dam workmen, with haphazard techniques;
- after detachment, the pieces of mosaic were piled outdoors in the garden of the Gaziantep museum;
- during all these operations, many mosaics were severely damaged. Some parts were lost altogether.

The conservation project

Given that every day after the dam was closed meant a 20 centimeter rise in the water level, the OAU archaeologists and the CCA conservators were asked to produce operative projects in a very short time and discuss them with staff at the Turkish Ministry of Culture. The plans were prepared, discussed, modified, approved and made operative in a week.

And in less than two weeks, thanks to the support of the PHI and the Turkish Ministry of Culture and the efficiency of the GAP, 120 archaeologists and 20 conservators arrived at Zeugma, completely equipped, ready to work.

In this extremely limited time, the GAP prepared a camp that could comfortably house 250 persons despite temperatures above 45 degrees C, set up the access and infrastructure needed for the excavation, and organized transport for all personnel involved; the ministry of culture and the archaeologists drew up the trench layout and the excavation schedule and transferred personnel; the conservators moved in personnel, materials and equipment, and set up an infrastructure on the site and laboratories for emergency field conservation; with the archaeologists, they arranged and discussed the work plans and tools for internal communication that would ensure that the conservation work proceeded smoothly during and after excavation without interfering with the archaeologists' work.

Basically, the conservation plan discussed and approved by the Turkish

Ministry of Culture was conceived to replace the previous practice of performing many unco-ordinated small restoration treatments with a global strategy based on principles of preventive conservation.

After a preliminary analysis, it was immediately clear that, given the situation as it was in June 2000 and considering that Area A (already excavated) was almost entirely under water without protection, all efforts should be concentrated on Area B.

There were three possible intervention options:

- topographic prospecting and survey of the archaeological structures visible in Area B and improvement of the reburial conditions, without starting new excavations;
- excavation of the area and systematic removal of the greatest amount of material and structures (as had been done up to that point);
- co-ordinated archaeological investigation and documentation with protection and reburial of the structures before inundation, including full recovery of movable objects and selective recovery of the structures.

A fourth option – asking the authorities for a considerable delay in closing the dam – was ruled out at the beginning, given the national priority of the operation and the long warning period that had passed without any strong reaction on the part of the scientific community.

The first option arises from the consideration that, based on the thermodynamic principles governing the decay of materials, where there is hygrometric stability, materials decay at an extremely slow rate. In the case of buried archaeological sites, structures and objects, after a period of relatively rapid transformation due to neglect and burial, they tend to reach an equilibrium that will preserve them over millennia (De Guichen 1984: 21). This consideration holds true both in the case of exposed sites and of sites under water (see the case of Baia near Naples). This consideration is also coherent with the recommendations of the ICCM, stating: "The fundamental premise of the preservation of mosaics is conservation *in situ* and/or its context" (Michaelides 2001: 13). This means that, in the specific case of Zeugma, if the site had been submerged in the same state that history had passed it on to us – i.e., buried – very little would have happened to the archaeological structures. As a result, the choice fell on option 3, which probably represented a halfway point between the needs of scientific investigation and the future protection and conservation of the site. Thus, the conservators' objective changed from preventing damage to containing it.

Thus it was decided to carry out an archaeological investigation in order to understand and document a portion of the city, chosen in view of the constraints imposed by the rising water, the time required for the archaeological work and the subsequent protection and reburial. Starting from the ethical premise of leaving as much *in situ* as possible, the removal operations involved all the movable objects and any structures in precarious condition or ones that the Turkish Ministry of Culture had decided that they could not be preserved *in situ.*

In particular, the choice of option 3 meant that the following new strategy was implemented for Zeugma.

New strategy approved by the Turkish Ministry of Culture	**Previous system**
All operations of conservation, restoration and protection are subject to a single co-ordination (TMC and CCA)	Each excavation group acted
The conservation plan is geared to cover what was previously excavated (Area A) and what will be excavated prior to inundation (Area B)	There were no conservation plans, let alone allocation of resources
The aim of the conservation plan is to protect finds and structures, facilitate their study, publication and presentation to the public	The rare restorations carried out were only cleaning for study purposes
Finds and structures will be treated immediately during excavation	No conservation treatment performed during excavation (except for detachment of the wall paintings and mosaics)
Systematic documentation of all structures	In the case of mosaics, documentation very poor (or not supplied to the TMC and conservators)
Selection of elements to detach on the basis of their condition and the possibility of protecting them *in situ*, the rate of the rising water and the opinion of the TMC	Systematic detachment of all mosaics and wall paintings with destruction of original structures and stratigraphy
Respect for and protection of all original structures left *in situ*, without hierarchical distinctions	Anything not detached was abandoned to the water without protection
Maintenance of the site after excavation	Excavated areas and the site abandoned between one campaign and another
Support for Gaziantep museum for the conservation and display of finds	No attention to the final destination of the collections (museum and public)

Turkish restorers currently working at Zeugma included in the organizational chart	Their presence was intermittent and they had no formal or financial coverage
Use of the project for conservation training	No training program was carried out
Maintenance of a high international profile in the composition of staff	All groups had a distinct national character

Technical treatment performed

Bearing in mind the problem of the rising water level and always striving to follow the principal of minimal intervention, the methods used in the treatment were the simplest and most rapid possible, in order to achieve the best results in the least time.

All priorities and conservation requirements were discussed and planned with the archaeologists, on the basis of a division of responsibility and cooperation defined at the beginning of the project. The simplest preventive conservation measures for the finds were performed directly by the archaeologists, who were constantly provided with information and support by the conservators. More complex operations were done directly by the conservators.

The trench supervisors acted as an interface between the conservators and the archaeologists through a continuous exchange of technical information and through discussion of operative programs and the drafting and updating of priority plans.

The conservators produced weekly work plans for the archaeologists in order to facilitate planning of the archaeological investigation. These plans were based on predictions from the dam company about the water's rise, combined with the time needed for technical operations of conservation, protection and reburial.

As a rule, and obviously simplifying the facts, the conservators' efforts were focused on five principal objectives:

- assist the archaeologists during excavation in order to limit, as far as possible, mechanical and thermo-hygrometric stress on finds and structures during excavation and facilitate the reading of the structures by cleaning to enhance archaeological documentation;
- remove movable objects and threatened structures;
- reinforce archaeological structures to be left *in situ*, using consolidation and contact protection, and restore the lines of original burial, in order to reproduce a stable thermo-hygrometric environment that can resist

the rising water;
- implement a maintenance program for the shore of the so-called "fluctuation zone" of the water, which is constantly battered by waves;
- restore everything that was excavated and removed from the site during the excavation campaigns prior to the PHI project.

1. Assistance to the archaeologists during excavation

Excavation and cleaning

During the archaeological investigation, the archaeologists were given technical tips on how to avoid damage to surfaces and objects during their work. With temperatures ranging between 40° and 50° C, the structures and finds constantly ran the risk of rapid moisture evaporation, leading to violent crystallization of the soluble salts they contained.

To mitigate this phenomenon, the work areas were shaded, and if a mosaic was discovered, instructions were to leave a 10 cm layer of dirt over its surface. This layer was subsequently removed by the conservators during cleaning, which was performed with soft plastic brushes, synthetic sponges, a 2% solution of NeoDesogen in water and a vacuum for liquids. The cleaning was always done by groups of 6-8 people in order to reduce the time of exposure of the surfaces to heat and air and avoid the formation of insoluble layers on the mosaic surfaces (fig. 3).

Documentation

After cleaning, documentation was carried out in the form of drawings, photographs and videos, in both traditional and digital formats. All the mosaics and wall paintings were recorded through 1:1 contact on polyethylene sheets, tracing all the lines of the figures and geometric motifs. For the mosaics, the surveys thus obtained, together with the photographic documentation, were then used as the basis for developing base maps in AutoCad for documentation of their condition, past treatments and the current conservation operations performed. Casts of inscriptions and graffiti were taken in silicone.

In all, 2000 film images, 2500 digital images, 12 hours of video shots, 250 m^2 of tracings, 160 CAD plates and 25 silicone casts were done.

2. Removal from site of movable finds and mosaics

As a premise, a determining component in the approved project was the removal from site of all the movable finds and structures that – owing to their precarious condition or to the opinion of the TMC – could not be kept *in situ.*

The operation called for a great effort of co-ordination with the archaeologists at work. It was either done directly by the conservators or, where possible, by the archaeologists, who had previously been instructed on what techniques and materials to use. All finds and detached mosaics were immediately taken to the laboratory and restored.

Of everything that was removed from the site, nothing has been left unfinished from the conservation point of view.

A total of 4000 finds and 160 m^2 of mosaics were removed from the site.

3. Protection of structures left *in situ* and reburial of the excavated areas

The primary consideration in deciding whether to leave a structure *in situ* or remove it was whether its condition offered a good prospect of success for protection and reburial before it was submerged. Before seeing the details of what was done, we should focus on the risks involved for the structures in the passage from open ground to the bottom of a lake.

This passage was characterized by an aggressive phase – the inundation – of extreme thermo-hygrometric instability, in the course of which the mechanical stress (wave action) affecting the archaeological structures was very great. Then followed the new, definitive state – below the water level – where the thermo-hygrometric stability was virtually total and the mechanical action of the waves virtually nonexistent. The true enemy to be dealt with was thus the phase of passage from open ground to lake bottom. Fortunately, it was very rapid, but still capable of destroying the archaeological structures through wave action that could undermine their stability – producing holes, washing away original material, rapidly soaking materials and causing their collapse. The following phase (when everything was already submerged) was less problematical from the conservation standpoint because the materials were again in a stable environment, close to 100% humidity. Given the water density and the thickness of the reburial materials, there were practically no thermal variations, just like the hygrometric variations. The water movement at depth had little influence, as the flow of 500 cubic meters per second was spread throughout the entire section of the lake – approximately 40,000 square meters – resulting in a nominal speed of 1.25 cm/s concentrated in the central area of the reservoir.

The so-called "fluctuation zone" was a different matter. This is a strip about three meters deep directly below the high water level. In this area, the water rises and falls continuously in relation to the workings of the dam, and it is also where mechanical wave action occurs. Potentially everything in this zone was threatened with destruction, so a specific plan for protection and maintenance was defined for the entire "fluctuation zone".

The solution devised to protect the structures before the inundation was as follows:

- consolidate supporting structures where necessary;
- apply a layer of about 5 cm of hydraulic mortar;
- rebury the areas under a layer of earth, river pebbles and stone, at least 50 cm thick.

The idea of applying the layer of hydraulic mortar came from the many cases in antiquity where sacrificial coatings or plaster were used on frescoes and floors, for reasons of health (epidemics), religion (censorship) or style (interior redecoration). Whenever we have had the occasion to remove these lime-based layers, we have found the surfaces beneath in pristine condition[3]. A "modern" verification of the method's efficiency came from analyzing the results of a similar covering applied in the late 1970s on 300 square meters of mosaics in Nora, in Sardinia[4]. Beneath the protective coating, once it was removed, the mosaics looked like as they had twenty-five years earlier. Another example is the protection of Phoenician funeral mosaics in Porto Torres, Sardegna, made in 1994 by ICCROM for the Soprintendenza Archeologica di Sassari.

Consolidation of unstable mosaic edges and tesserae

Before applying the surface protection layers over the tesserae, it was necessary to consolidate all the unstable areas. For this purpose, we used infiltrations of hydraulic lime composed of sifted stone dust, brick dust and Lafarge hydraulic lime (ratio 1:1). This operation was performed both to fix the loose tesserae to the bedding layer and to consolidate the edges of lacunae. Where the various preparatory layers had separated, they were injected with hydraulic mortar made with sifted brick dust and Lafarge hydraulic lime (ratio 1:1). Lacunae and edges were also reinforced with hydraulic mortar containing stone dust, applied and worked with spatulas, proceeding as follows:

- mechanical removal of accumulations of dirt and deep roots along the edges and in the lacunae, using scalpels and vacuuming up the deposits;
- stuccoing of edges and lacunae with a lime-based mortar (Lafarge hydraulic lime, slaked lime, sifted brick dust, limestone dust in a ratio of 0.5:0.5:1:1).

Surface protection prior to reburial

A coat of lime whitewash was brushed directly onto the cleaned and consolidated mosaic surface. This coat has the double function of further

3. Rome, Roman Forum, Republican houses; Rome, Cripta Balbi, basement floors; Zippori, Israel, house of birds and fish; Cesarea Marittima, Israel, baths on the sea.

4. Archaeological Superintendency of Cagliari. Roman Punic city of Nora. The treatment was performed for conservation purposes by Dr. Carlo Tronchetti in the late 1970s.

consolidating the mosaic surface and acting as a buffer between the original surface and the next protection layer, thus making the latter easier to remove in the future.

When this coat had dried, the protective layer was put on – a 5 cm thick layer of hydraulic mortar composed of Lafarge hydraulic lime, slaked lime, brick powder and stone dust in a ratio of 0.5, 0.5, 1.5, 0.5. This layer was extensively worked to obtain perfect adhesion to the surface beneath it and improve the carbonation process of the aerial components of the mixture. This new surface will protect the original from the mechanical action of the water and act as a sacrificial layer. At the same time, its hydraulic character will enable it to continue to set in contact with moisture and there will be a progressive improvement in its mechanical resistance. In this way, every exchange with the environment will occur on the applied layer and not directly on the original (fig. 4).

The choice of hydraulic mortar was dictated by its high resistance, its mechanical and hydraulic qualities, its durability and complete compatibility with the original surfaces (fig. 5).

Reburial of the excavated areas

All the trenches and structures were reburied with a double layer of materials: the first was composed of soil and sand and was about 50 cm thick; the second was also 50 cm thick on average and composed of river pebbles and stones.

The soil and sand applied in direct contact with the structures were dampened and packed to prevent shrinkage during the inundation. Particular care was taken in filling cisterns, covered rooms and irregularities in the terrain to prevent collapses that could damage pavements and building floors. These operations were done by hand, with wheelbarrows and shovels. Mechanical means were used as much as possible for the other reburial work. Generally, all the trenches were filled with a first layer of soil and sand about 50 cm thick, followed by a variable layer of pebbles and stones depending on the slope of the trench. A total area of 8700 m^2 was reburied, covering 19 excavation areas. The volume of materials used for reburial was 10,500 m^3, equivalent to 630 truckloads of sand, pebbles and stone (fig. 6).

4. Post-Excavation Site Protection and Shore Maintenance program

A few months after the excavation ended, it was clear that in some areas the protection measures implemented during the excavation could not withstand the ongoing erosion in the fluctuation zone (383–385 meters). The energy built up by the waves was great enough to remove and/or disrupt the heavy pebble covering (average stone size ranging from 10-20 cm in diameter) put in place when the excavation was closed. Furthermore, the wave action continued to disturb unexcavated zones on the shore, constantly bringing up archaeological remains. In some places, artifacts, such as wall plasters and mosaic floors protected during the excavation, were uncovered; while the protective lime-based mortar layer withstood the environmental threats quite well, the structures supporting the artifacts themselves proved to have little or no resistance to the erosion activity on the waterfront. The mud stone walls (Ashlar) started crumbling away, and the floors were often set on not reinforced ground undermined by the water. It was clear that further protection measures were necessary to minimize damage to the archaeological layers in the water fluctuation zone.

To improve the efficiency of the protection system set up in October 2000, the following measures were implemented: rows of woven plastic (nylon) bags filled with gravel (1-3 cm diameter) were arranged parallel to the shoreline. These were piled on each other according to the slope of the shore, between 2-4 bags high. The nylon bags do not last well outdoors as they are susceptible to UV radiation, so the uppermost row of bags was filled with gravel mixed with cement. Behind this barrier, heavy pebbles (10-20 cm diameter) were filled in up to the high water mark under storm conditions. Where the shoreline configuration allowed it, a double row of bags was arranged at 2-5 meters apart. The space between the two bag walls was filled with pebbles.

After a month, this solution also showed a weak point in the material of the bags. The plastic deteriorated very quickly, spilling the filler into the water and polluting the environment. It was therefore decided to move toward the local traditional canvas sacks which are completely biodegradable. The durability of those sacks was intended to be the time required for the gravel/cement mixture to dry up in its final location and shape.

The protective measures were put in place by local manpower, using tractors equipped with dump-load trailers under the supervision of conservation professionals. A total of 5000 bags and 85 truckloads – equivalent to 850 cubic meters – of pebbles were used. To maintain an area of 8000 square meters (the shoreline, 1.5 km) in good condition during the first year after excavation, 600 working days were required plus materials and machinery. This represented a total cost of $20,000 US, i.e., $2.5 per square meter per year. These data were confirmed during 2001-2002.

The maintenance will continue until evidence shows that, thanks to the measures taken, a new equilibrium has been achieved.

5. Restoration of material excavated and removed from site during the excavation campaigns prior to the PHI project

The key priority of the new Zeugma project was to keep pace with restoring new finds as they were excavated, while also treating what had been removed from the site during previous campaigns.

With regard to movable finds, this priority meant restoring some 1800 objects, including the famous bronze statue of Mars. For the mosaics, our first concern was to put them into adequate indoor storage (before rain and snow arrived) and begin a new sort of "archaeological excavation" in the mountain of fragments in order to reconstruct the context of their provenance and give the artifacts a "name and surname". The result was a list of about 700 square meters of mosaics, mostly polychrome, figurative and geometric, detached from the site with various methods and generally in drastic condition.

The restoration treatment was completed on March 2003.

Other initiatives

As mentioned earlier, one of the main objectives of the project approved by the TMC was to develop – parallel to direct conservation activity on the site and its artifacts – a further series of typical preventive conservation activities.

Some of these activities are still going on; some will continue on their own in the future. In any event, after three years we can evaluate the first results in both cases. Here are some of the activities:

Conservation initiatives:

- the Gaziantep museum, which is responsible for Zeugma, has been supplied with two perfectly equipped laboratories, covering a total of 250 square meters, for restoration of mosaics, wall paintings and movable objects;
- the same museum has been equipped with one storage area for movable finds and another for mosaics;
- an alarm system was installed in the storage depot and laboratories, and a climatic monitoring system was installed in the museum.

Information initiatives:

- the collection on display in the museum has been given special attention, with mosaics, wall paintings and finds constantly being added;
- all the restoration work performed during this period in the laboratories has been accessible to the authorities, the press and organized groups. Through lectures and guided visits, museum visitors have been informed about the progress of the work.

Training initiatives:

- in the course of 3 years, 10 Turkish technicians have been trained or given further specialization in mosaic restoration and 3 in metal restoration;
- a group of 6 Turkish workers has been organized for site maintenance;
- a procedure for hiring 3 Turkish technicians for Gaziantep museum is in process for restoration and maintenance of mosaics;
- two specialization courses were held for 5 Tunisian restorers from the Institute du Patrimoine de la Tunisie.

Awareness-raising initiatives:

- a seminar on preventive conservation has been held for staff of the GAP involved in territorial development and for functionaries of the TMC;
- there have been direct and ongoing contacts with local and national authorities and industrial groups to facilitate sustainable development of the Gaziantep museum facilities, the Zeugma archaeological park and cultural tourism in this rapidly developing region.

A final consideration is that we have tried both to maintain a high international profile for the project – with conservator-restorers from Brazil, France, Germany, Italy, Spain, and the United States – and also to strengthen the local, national component: the Turkish presence in the organization chart has grown from 20% at the beginning to 50% today.

Conclusions

The Zeugma project was an enormous challenge for the archaeologists and conservators, given the methodological, technical, climatic and organizational issues involved. While a project such as this required a strictly organizational effort from the practical and logistical standpoint, from the methodological standpoint, the choices adopted called for taking a position with regard to an ethical principle – *in situ* conservation. This approach had not been considered – more for environmental and conservation reasons than for methodological, let alone organizational ones.

This is certainly the issue that has elicited the most discussion, and will do so in the future: the choice of preserving what could be preserved *in situ* as a function of the possibility of providing efficient protection.

Permit me to clarify a couple of points that might help to settle the dust that has been raised about this project, or at least about the choice of following the principle of *in situ* conservation: it did not represent a systematic practice to be applied indiscriminately; rather, it involved replacing a practice used in an extreme way up to that time with a more flexible criterion, introducing a selection criterion based on technical factors and, moreover, always subject to the judgment of the TMC – the authority responsible for the site.

Thus, it was not a question of applying a "rigid doctrine of *in situ* conservation", but rather of interrupting a "rigid doctrine of detachment".

Yet, I feel the most important thing to stress is that the primary goal of this program was to broaden the perspective and the final objective of the conservation treatment and the excavation itself, shifting the common focus from individual objects or pavements toward a more all-inclusive strategy.

Such a strategy is designed around the themes that characterize modern-day conservation: documentation, protection, training, information and – more generally – respect for the integrity of the archaeological heritage, with particular attention to developing local resources so that the accomplishments of three years' work will be sustainable in the future.

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FIGURES


fig.1


fig.2


fig.3

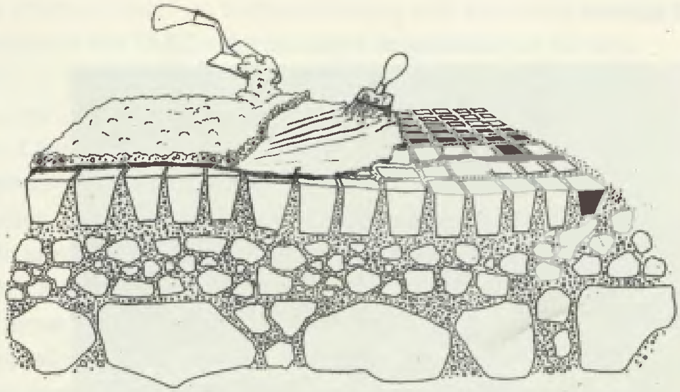

fig.4

fig.5

fig.6