

LASER SCANNING AND INFRA-RED THERMOGRAPHIC PROSPECTING FOR DIAGNOSTIC MAPPING AND RESTORATION PROJECTS: THE CASE THE PAINTED TOMBS AT CYRENE (LIBYA)

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ABSTRACT:

The team of Chieti University is involved in a GIS project of the monumental rupestrian necropolis of the Greco-Roman site of Cyrene (Libya). Because of the large number and of the monumentality of the tombs and of the rocky sanctuaries, the team is composed of a large number of scholars and technicians, including archaeologists, topographers, geologists, anthropologists, biologists, natural scientists, restorers and architects, working together and using different technologies, both for mapping and for projecting restoration and valorisation of these splendid but almost unknown monuments. In order to explain the methodologies and the technologies in use for this project, the Painted tombs of the northern and southern necropolis are presented in this paper, as examples of the technical protocols and of the multidisciplinary approach converging into a multilayer GIS project.

1. INTRODUCTION

1.1 The project: general issues

Cyrene has certainly one of the most spectacular and well preserved rocky necropolis of the Mediterranean Basin (Cassels 1955; Thorn 2005), but at the same time it is the least known by the scholars. The funerary area consists of myriads of tombs alternating with impressive rocky sanctuaries, which represent the most vivid example of mixture and integration between Greco-Roman and Libyan cultures, with a strong cultural and topographical impact on the local background, showing great example of rupestrian Greek architecture.

The vastness, the density and the monumentality of the whole area made necessary a systematic project of survey, excavation, GIS mapping (see Appendix below and fig.7) and documentation of this huge but neglected patrimony. The team from Chieti University started in 1999 (Fabbriotti 2006; Menozzi 2007, 2008, 2010) a project of surveying and mapping of the southern and eastern necropolis, giving birth to a GIS using DGPS and Robotic total station for positioning and recording the tombs and multispectral HD satellite images, previously ortho-rectified and geo-referred, combined with RADAR data for highly detailed topographic base, DEM and DTM. From 2004, the survey and the GIS have been extended also to the western and northern necropolis, counting at the moment about 1500 mapped and recorded tombs (see Appendix and fig.7). The project involves the use of field survey and excavation in combination with remote sensing on aerial and panchromatic satellite HD images, geological surveys and analysis, geo-archaeological non invasive prospecting (using mainly magnetometric methods), DGPS positioning, archaeometric analysis, constituting levels of an integrated multilayer GIS database working as collector of the huge amount of data (Cherstich, Fossataro, Menozzi 2010; Menozzi, Fossataro, 2010).

A natural consequence of the wide differentiation of scientific approaches is the use of a large team including in the project scholars and PhD students with very different backgrounds,

provenances, attitudes and experiences. From the large amount of results it is now possible to create models of the evolution of the necropolis, looking to its landscape assessment, to its growth in combination with the urban context, to the development of the architectural typologies of the tombs, in order to contextualize more properly, chronologically and topographically, the evolution of this monumental 'city of the Dead'.

The GIS mapping of this large amount of funerary monuments and tombs, includes rocky chambers with architectonic Doric, Ionic and Aeolic porticoes and decorations, monumental *loculi* and sarcophagi, painted and inscribed tombs, funerary courtyards, tumuli, *mausolea* and mastabas, as well as rocky sanctuaries closely related with the funerary cults and the local Libyan culture. The GIS of Chieti University (Fig.7), which is carried out in collaboration with the local Department of Antiquities, is yearly updated with seasons of intensive field survey, specific excavations in sensible areas, remote sensing and geo-prospecting.

The huge amount of data coming from this project are at the moment stored in the Archive of the Archaeological Mission of Chieti University and in the Department of Antiquities of Cyrene, both containing not only the geo-database of the GIS project, in ArchView version (ShapeFile), but also photos, drawings and notes. However, our team is now projecting the possible publication on a Google Earth platform, with complete dataset in a remote version, and a lighter version of the geo-database in a public version. This further step could allow a wider use of the data and a larger possibility of project in collaboration among different institutions and teams working for common purposes.

This typology of innovative and multidisciplinary approach is particularly important at the moment for Cyrene, because of the strict need for this site to respect the new UNESCO parameters and protocols, asking to the local Department of Antiquities for new maps of the archaeological site, more detailed buffer zones delimitations and constant diagnostic mapping of the remains, especially after the recent conflict.

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In this sense the GIS project, in general, is certainly a great help for the local authorities, representing also a field for strict collaboration with them, and at the same time can offer to the UNESCO important tools for monitoring and controlling the developments and the urbanization in this site, which are among the main UNESCO objectives.

Moreover, the GIS, using basically ArcView (9.2 and 10.1) and QGIS software, has been planned also for a simplified version using Google Earth protocols, in order to transfer more easily geo-referenced data both to the Departments of Antiquities in Libya, as well as to UNESCO offices or to other teams working in Libya, where other Italian, French, English, Polish, German and American Missions are working and could exchange data and information more easily through a common geo-database.

1.2 The Diagnostic mapping of the painted tombs: aims and methodologies

However, together with a topographic and architectonic approach of research, the team is also applying the most recent technologies for diagnostic reason, in order to have a clear situation also of the problems of preservation of these monuments, mapping, as a layer of the GIS, typologies of damage, risks, act of vandalisms, and possible suggestions for restoration and conservation for these monuments.

We intend to present here, as example of the methodologies and technologies used in this project, just the case of the monumental rupestrian painted tombs of Cyrene, from their mapping, digital high definition documentation, archaeological, geological and biological analysis, to the results and to the suggestions for projecting their conservation, restoration and valorisation.

The painted tombs represent a rare and precious group of funerary monuments in the northern and southern necropolis at Cyrene, and they are also particularly delicate, for their easy accessibility, constant frequentation, frequent aggression by natural agents, decay of the paintings and phenomena of vandalisms deteriorating frescoes and plaster, also considering the recent war event, which have not caused large damage inside the town of ancient Cyrene, but in its *chora* and necropolis have caused more problems.

From the methodological point of view the documentation of these tombs have been based on several steps, aiming a complete mapping and analysis of the damage, before planning interventions of conservation, restoration and future valorisation.

First of all the tombs have been scanned with a HD laser scanner, with two scanning for the external facade and per each internal side at a high definition, with a even higher definition for the painted and plastered areas. During this phase, the laser scanner, which has got its own internal photo-camera, has taken several photos of the internal and external views, in order to use the photos to give the natural appearance to the monument, thanks to the merging of the data in post processing. In this way the damage can be mapped both on reconstructive 3D models of the tombs, but also on 3D real reconstructions of the monuments with their own real appearance and with the possibility of a precise navigation within the model. Moreover, scanning the monuments every year can allow also to follow the development of the damage and the time of the decay of the paintings, monitoring in this way more systematically and constantly the monuments.

A second step has been the photogrammetric documentation with a high definition photo-camera, helping in the interpretation of the remains of the paintings, documenting with more detail also their smaller damage. In post processing,

moreover, it has also been possible the merging of the high definition photogrammetric shots with the data of the laser scanner.

A following step in the protocol has been the analysis of the monuments with the infra-red photo camera, which has been fundamental to individuate the main wet areas, problems of humidity, micro-infiltrations and their consequences as lichens, *fungus*, *algae*, *cyanogen-bacteria* and detachments of plaster and paintings.

Moreover a further fundamental step has been the archaeometrical analysis of samples (including thin section and SEM analysis) of the paintings and of its plaster bases, in order to understand the composition and the micro-stratigraphy of the paintings and to plan more carefully the consolidation of the paintings.

A team of restorers have analysed our reports and documentation and verified the damage, suggesting the possible solutions case by case, integrating our detailed mapping of the damage with the solutions then proposed to the local Department of Antiquities.

A biologist has also surveyed the tombs, in order to make database and mapping of the biological micro-organisms deteriorating the paintings and the limestone. This has also been a very useful base for the conservative project.

However, one of the main problems of these tombs is also due to their total abandonment, to the not existing valorisation and safeguard, to their too easy accessibility without fences or limitative enclosure, exposing them every day to vandalism, to not proper frequentation, robbery, internal barbecues, which became even more problematic during the recent war, when this rocky funerary chambers were used as refuges. Therefore, a collaboration with architects, has made also possible a further step in our project, that is an hypothetic plan of valorisation and safeguard of these monuments, recuperating also their background, planning for tourist tracks and projecting possible solutions for using fences or enclosure to prevent future new damage after the restorations but with an impact to the natural and archaeological background as lowest as possible.

2. THE PAINTED TOMBS OF CYRENE

2.1 Tomb N 241: Tomb of the Good Shepherd (northern necropolis)

The so called 'Tomb of the good shepherd' (Bacchielli, 1990-91), consists in a rocky chamber tomb, with 4 inner monumental *arcosolia* on the lateral sides and a larger and central *arcosolium* on the main side, just in front of the entrance (Fig.1). The floor level of the tomb is lower than the external level and therefore a small staircase at the entrance gives access to the funerary chamber, emphasising the passage to the funerary room. The external façade is not particularly elaborated, it does not presents any architectonical decoration and shows a plain facade. The area just outside the tomb is characterised, as usual in Cyrenaican rocky tombs, by an external squared courtyard, creating a sort of sacred area devoted to the tomb, and delimited by remains of the original rocky slopes, which have been in antiquity cut and adapted and partially integrated by artificial sections of walls, to create a *temenos* of the funerary space.

Concerning the paintings, they are located on the *arcosolium* at the northern-eastern corner, and on the facade of the sarcophagus just below it. The iconography of the *arcosolium* presents a peacock standing on a *kantaros*, which are

surrounded and emphasised by garlands and fishes, with strong references to Christian symbolic representations. The front of the sarcophagus, just below this *arcosolium*, has represented a shepherd with its flock, and carrying one of the sheep on his shoulders, again with a strong Christian symbolism remanding to the well known iconography of the 'Good Shepherd'.

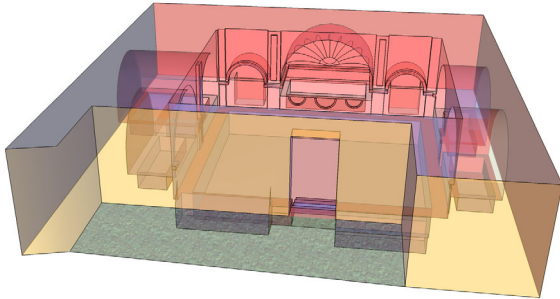


Figure 1: 3D model of the tomb

The monument shows several phases of use, with an earlier Hellenistic phase and later interventions. However last interventions, including the paintings have been dated to the end of the 4th-beginning of the 5th centuries AD.

The laser scanning of the tomb has allowed a precise volumetric documentation, giving the possibility of thematic plans, sections, prospects and drawings of details. The photos taken directly by the internal camera of the laser scanner (Fig.2) have been able to locate precisely the remains of the paintings, as well as the most evident problems affecting the tomb, such as lichens, modern writings, damage and so on. The photogrammetric documentation, then, undertaken with a high definition camera, after the post processing, allowed a better reading of even the smaller details, representing a great base for the mapping and analysis of the degradation and for the project of consolidation and restoration.

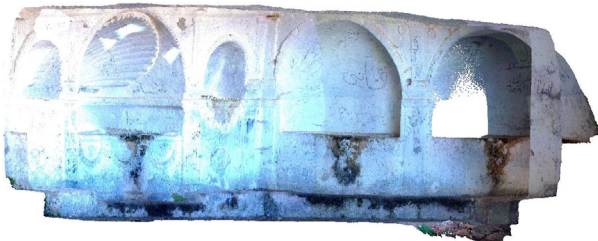


Figure 2: View from the laser scanning of the tomb

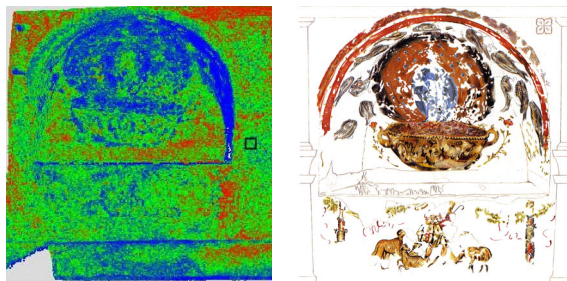


Figure 3: IR Thermography of the painted *arcosolium* (on the left) and reconstruction (on the right) of the paintings.

The infra-red analysis (Fig.3), which have been widely employed for this tomb, has been able to show many problematic areas, especially for the high concentration of humidity, such as along the western internal side, especially at

the corners, as well as area exposed to the direct light which has caused the proliferation of invasive *heliophile* micro-organisms. The problems therefore mapped for this tomb come from different origins. Most of the problems comes from humidity causing the proliferation of moss on the lower painted area. There is also some damage due to some modern writing, graffiti and drawings, mainly obliterating and in some case damaging the inner plastered, sculpted and painted surfaces. A greasy patina is covering the upper paintings and the inner sides of the rocky funerary chamber, mainly due to the dusty atmosphere in combination with occasional fires, because of the easily accessibility of the tomb therefore and used for picnic. A homogeneous level of white painting, probably done in the 40s of last century for reusing the tomb (which is quite frequent in Cyrene's necropolis) is covering most of the inner surfaces, stopping the proliferation of musk and lichens, but covering other possible paintings. The presence of accumulations of soil and litter within the lower sarcophagus just below the painted area, is increasing the rise of condense for paintings and their plaster base is transmitting for capillarity even more quickly moisture and microorganisms.

2.2 Tomb N 22: Tomb of the Ludi (northern necropolis)

The paintings are very badly preserved, but presenting very interesting subjects, thematically homogeneous and running all around the four sides of a rectangular rocky funerary chamber, showing several typologies of ancient games, both gladiatorial, hunting, musical and athletic competitions, carriages racings, Greco-Roman wrestling (Fig.4). The paintings date to the Roman Imperial period (Bacchielli, 2002a; Bacchielli, 2002b). The first step to document the tomb has been the photogrammetric documentation, which has been done both on dry and wet paintings.

Then the documentation has been compared with the old photos and drawings, in order to understand how much the damage are growing. The laser scanning in this case has not been possible because of the problematic light.

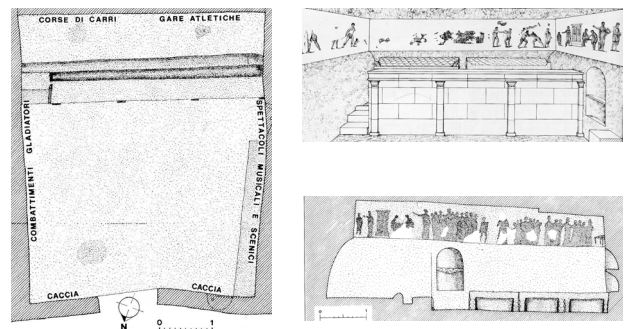


Figure 4: The tomb of the Ludi and the inner decorations

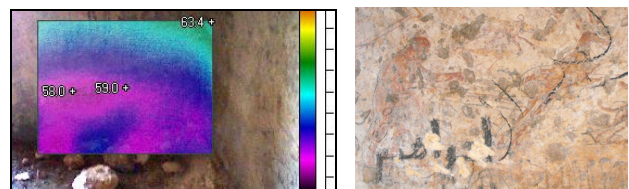


Figure 5: Infra-red thermographic shot: example of a humid area (on the left) and particular of the paintings (on the right) showing some of the problems affecting them

The problems presented by this tomb are mainly due to a lot of modern writing and graffiti on the paintings, on the walls and on the ceiling (Fig.5). Moreover, a greasy patina on the paintings and evident remains of firing and picnic are quite evident.

There is also a technical problem of the paintings, which is due to the use in antiquity of very diluted colours and of a very thin base of preparation, which makes even more difficult their preservation and caused already partially loose of some areas of the paintings. The concentration of moisture (Fig.5) in specific areas both for micro-infiltrations, capillarity and for rising humidity from below, generally due to the presence of accumulation of soil and rabbles, is causing the proliferation of micro-organisms in the lower sections of the walls and saline efflorescence in the upper part due to the typology of the local limestone, rich in mineral salts.

2.3 Tomb N 83: Tomb of Demetria (northern necropolis)

It is similar in plan to the so called Tomb of the Good Shepherd, consisting in a rocky chamber tomb (Fig.6), with a very simple façade, an external courtyard, and with *arcosolia* inside, covering burials in form of sarcophagi directly cut into the rocky bed. The *arcosolia* present shell decorations in three cases (the central one and the southern ones), a plain surface in the case of the north-eastern *arcosolium*, and a painted *arcosolium* in the north-western corner, as well as a painted inscription just at the left of the entrance, mentioning the owner of the tomb, *Demetria*, and her son, both dead during an earthquake, dating to the last decades of the 4th century AD (375) and dating then the paintings (Bacchielli, 1992).

The painted *arcosolium* (Fig.6) shows walls decorated with a polychrome grid pattern, reminding to the fences of a garden; while the ceiling presents a *paradeisos* scene, with flowers, different kinds of birds, peacocks and fishes below a male figure, suggesting again a strong Christian iconography.

The first step for documenting the monument has been the complete high definition laser scanning of the tomb which allowed a 3D mapping, which has then be used both as base for the diagnostic mapping and for 3D model and reconstruction of the tomb. The second step has been the photo-documentation directly taken, in this case, by the camera of the scanner, with photos which have been used to reinstitute the natural appearance to the interactive 3D models coming from the post processing of the data.

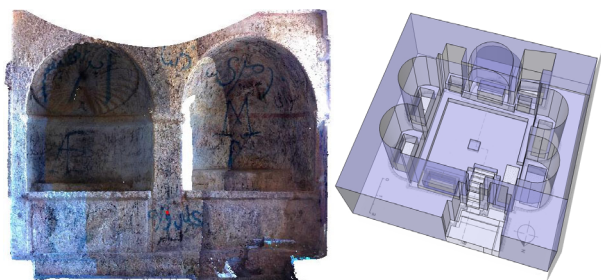


Figure 6: Laser scanning of the painted and decorated side and 3D model of the tomb

The third step has been the infra-red photo documentation, which has been able to show in a more detailed way the degree of the deterioration of the monument, including its areas with a high percentage of humidity.

Among the problems suffered by this monument, apart from modern writings and graffiti, there are areas with high quantity of mould and litter in the floor close to the lower part of the

walls, particularly of the east wall, causing area of high density of humidity and micro-organisms. The tomb has been also the site of recent fires and the sarcophagus at the centre of the back wall is marked by signs of tea waste thrown there. There are numerous charcoal and spray paint writings.

The recent survey and documentation of the painting has allowed also to identify many new decorative details such as: the front cist imitating a garland sarcophagus and shows two different layers of plaster and paint; the case frame, which has a guilloche; the right pilaster, which has a guilloche and bands of red paint; the *arcosolium* conch with the *paradeisos* scene, and at least 4 new birds and flowers can be identified.

2.4 Tomb N 173: Tomb of Ammonius the Veteran (northern necropolis)

The tomb consists of a funerary chamber with *loculi* burials and presents paintings on the walls and on the ceilings of the chamber. The monument is very badly preserved, both inside and outside. The charcoal drawings and writings strongly covering most of the paintings, but they can be easily removed, because they do not show incisions on the paintings. Some moisture is affecting the lower part of the funerary chamber, with higher concentrations in the corners, including the entrance and the bottoms of the *loculi*. The moisture seem to be thicker nearby the plaster and the old cement restorations. Encrustations for saline efflorescence, plaster detachment and rock calcification have damaged the wall presenting again a *paradeisos* scene (peacock, birds, vegetal and floral decoration) in the first panel. For the rest the paintings do not seem to have been too badly damaged. After a proper restoration this tomb could become one of the most important ones in the Northern Necropolis, with its wall-paintings, vivacious decorated ceiling with polychrome geometrical and floral patterns and funerary accoutrements.

The tomb has been documented with the infra-red thermo-camera, with photogrammetric survey and with remote sensing on post-processing of photos and thermo-camera shots. It has not been possible to use the laser scanner, because of the inaccessibility of this monument with delicate equipment. The documentation and photogrammetric reconstruction of the polychrome ceiling has been particularly difficult, but the high definition images and IR thermo-camera shots have been very useful for a detailed diagnostic analysis.

2.5 Tomb S 64: Tomb of the illusionistic architecture (southern necropolis)

The tomb S64 was already known as monumental rocky tomb with an antechamber and a funerary *loculus* chamber (Fig.7), but the paintings have been seen and identified just recently during the survey of our team (Cherstich, Santucci 2010). The tomb can be seen along the modern road linking ancient Cyrene to Balagrae, along a still well preserved track of the ancient Greek and Roman road. The front of the tomb hosts still part of the real architecture in course of ashlar masonry. The interior is organised in two sections. The first room is a rectangular antechamber with painted decorations, which acted as an introduction to the tomb, while the second room with its two series of double *loculi* hosted the burials. The sides of the external large squared courtyard host other rupestrian tombs and small niches for portrait busts, statues of the so called 'funerary goddesses' (so numerous and typical of Cyrenaican funerary uses and sculpture) and reliefs. The tomb is now used as a repository for agricultural tools. All the burials were looted in indefinite time periods. The tomb has been widely documented

with graphic and photographic survey, macroscopic analysis of moulds and lichens; infrared and photogrammetric survey, drawings and graphic reconstruction of the walls. The infrared survey has been done at a constant distance of c. 1.3 m from the walls, because as also the light exposure and the temperature, the distance from the walls is one of the factors determining the good results of the data.

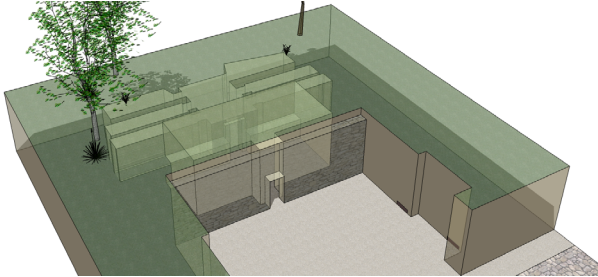


Figure 7: 3D model of the tomb with axonometric view

The problems presented by this tomb are quite similar to the previous ones. The wall of the first room are heavily covered by smoke signs. The wall paintings are damaged by charcoal graffiti and incised writings. Probably the soil above the tomb (which now hosts a vegetable garden) is not very thick and the irrigation water freely penetrate from above where the rock is collapsing. The wall-paintings are concentrated along all sides of the antechamber and they were used to integrate the benches and the architectures of this room, with illusionistic painted architectures, showing balusters, Doric porticoes and friezes, with portraits and statues among the columns, with an illusionistic perspective and the use of light yellow and red for the architectonic decorations and blue for creating chiaroscuro effects. The restoration, which is still in progress, will probably help in recovering many more elements.

3. CONCLUSIONS

3.1 Results and applications

The combination of different technologies, methodologies, scientific approaches is allowing, in the case of the painted tombs of Cyrene, as well as in general in the case of the necropolis of this site, a multilayer project focused on documenting the damage for a diagnostic step, on topographic and geological surveys for contextualise these rupestrian monuments, on the study of the iconographic apparatus, on the archaeometrical analysis. Moreover this large amount of data is now at the base of the project of conservation and valorisation, including also a plan for the safeguard of the monuments and a study of the impact on the local landscape of possible fences, enclosures and infrastructures for a sustainable tourist exploitation of the necropolis and its splendid monuments. The innovative approach, including the use of DGPS, laser scanner techniques, non invasive geo-archaeological prospecting, Remote Sensing, Infra-Red documentation and Archaeometric analysis for diagnostic purpose is giving results in real time processing, accelerating enormously the process of mapping (especially comparing with traditional mapping as it has been done till recent times at Cyrene) with surveys not only focused on topographic matters, but also aiming diagnostic purposes and continuously monitoring the situation of the huge and monumental necropolis.

This protocol, which has been fully applied at the moment only to the necropolis of Cyrene, has also been adapted in an experimental way, to the study of the mosaics at Ptolemais, with

similar purposes of diagnostic monitoring and valorisation project.

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3.4 Appendix: GIS of Cyrene

The GIS is organised in several levels, from a 'macro-GIS', showing the sites in a regional scale on wider Satellite bases (FC Zulu and Landsat), to the GIS of the site of Cyrene on HD Satellite Images. In this context, the figure below shows a general view of the GIS in progress of the monumental rupestrian necropolis of Cyrene on HD panchromatic Satellite image, with the location of the main tombs (dots), of the ancient urban area, and of the *temene* of the main ancient extramural sanctuaries. The painted tombs are indicated with their numbers and contextualised in their original locations.

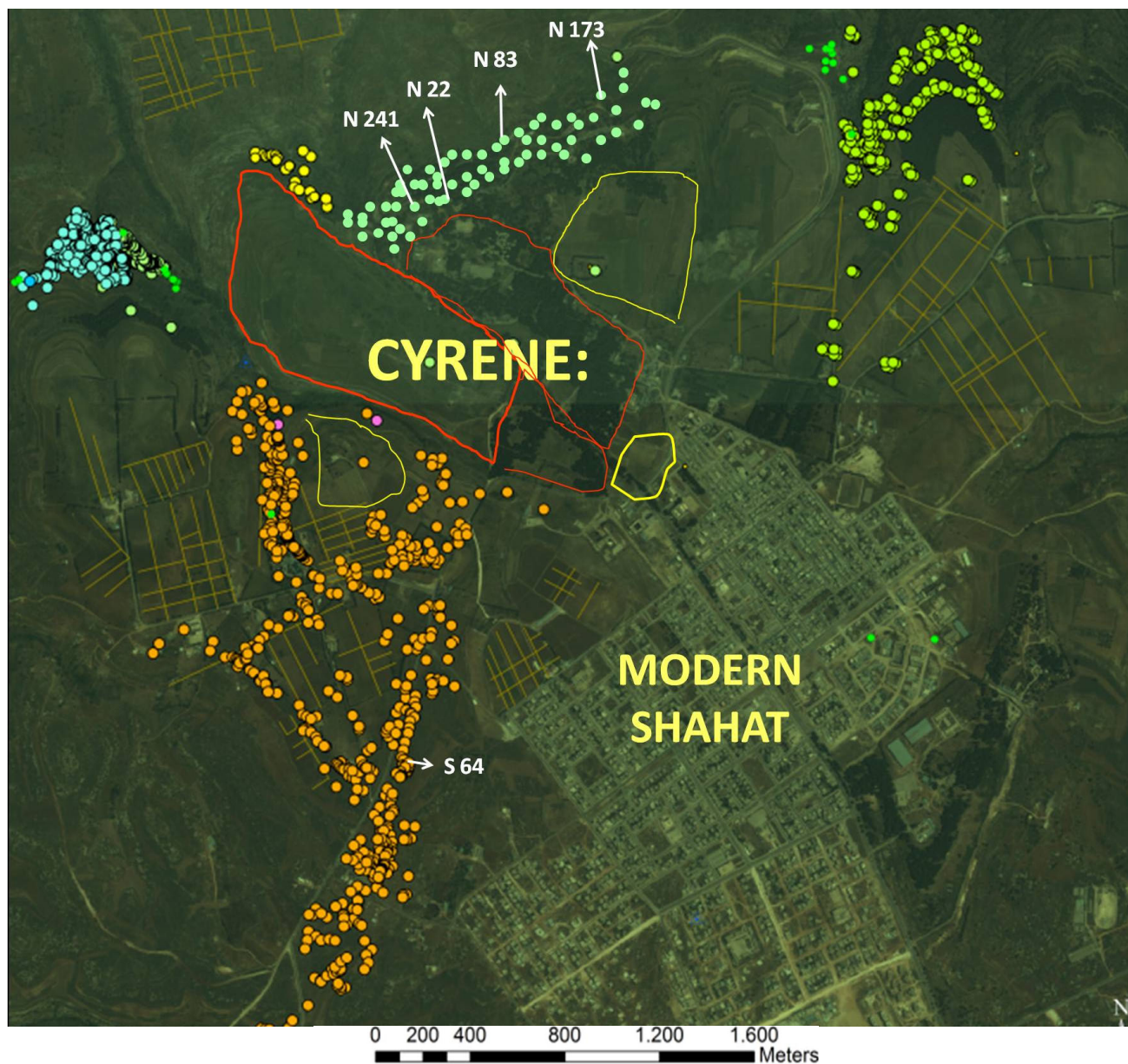


Figure 7: General view of the GIS of the territory of Cyrene, with its necropolis and extramural sanctuaries