IMTO – Italian Mission to Oman

University of Pisa

SUMHURAM

PRELIMINARY REPORT

January – March 2007

(SUM07A)

SUM07A

The first IMTO's campaign of 2007 (SUM07A), directed by Alessandra Avanzini, started on 20.01.07 and finished on 17.03.07.
The IMTO's activities were focused in different fields, thanks to the participation of scholars of different subjects.

Regarding the city of Sumhuram, the main goal of this campaign concerned the excavation and restoration of the north-eastern sector of the city walls.
The excavations were conducted by dr. Alessandra Lombardi and dr. Benedetta Bottoni.
Dr. Said al Mashani was responsible of the management of all the working operations in Sumhuram.
The consolidation and restoration of the ancient masonry structures, under the direction of prof. M. Sassu (Department of Structural Engineering, University of Pisa), were conducted in the field by dr. eng. F. Rosa, dr. eng. C. Cei, dr. eng. L. Angelini, dr. A. Gioeli, dr. F. Mollica, dr. A. Soru.

From 25.02.07 to 06.03.07 a three-dimensional topographical reconstruction of the city of Sumhuram and surrounding territory has been conducted by dr. Eva Pietroni and dr. Niccolò Dell'Unto (Institute of Technologies applied to Cultural Heritage of CNR of Rome).
Related to the same project, dr. Fabio Rossi and dr. Chiara Evangelista (Laboratorio PERCRO, Scuola Superiore S. Anna, Pisa) were working in three-dimensional reconstruction of the most important small findings from Sumhuram, through laser scanning.

From 25.02.07 to 07.03.07 a team of botanists from the University of Florence, composed by prof. M. Raffaelli, Mr. M. Tardelli and dr. S. Mosti, was engaged in botanical research in natural park of wadi Doka and in arrangement of the botanical garden of Al-Balid.

The work of IMTO has been possible thanks to the collaboration of the Office of the Adviser of His Majesty the Sultan for Cultural Affairs in Muscat and in Salalah. In particular, we would like to thank Hassan al-Gabri, Ghanem al-Shanfari, Ahmed al-Awaid, Said al-Mashani and all the Museum's team.

Salalah, 14.03.2007

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January – March 2007

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ARCHAELOGICAL PRELIMINARY REPORT (SUM07A)

January-March 2007

During the campaign in the spring 2007, archaeological investigations were conducted in different areas of Sumhuram.
In particular, the external area A7, corresponding to the grid squares h/i-13/14, has been completely excavated.
In addition, in order to lighten the pressure of the filling on the internal side of the city walls in restoration, three rooms in Area A, already partially investigated by AFSM mission, have been again excavated.
Inside the city gate complex, before the complete rebuilding of the collapsed eastern wall (M3) of the tower A6, a deep sounding has been conducted along the two contiguous walls M3 and M12, in order to clarify the relations between the two walls and their levels of foundation.
Finally, also the north-eastern corner of the city, occupied by two big masonry structures, has been almost completely excavated.

External Area A7 (trench supervisor B. Bottoni)

Starting from the eastern limit of the city wall M14, already found during the SUM00A campaign, a long sector of the north-eastern city wall has been completely unearthed.
Three different sectors of the city wall (M220, M221 and M223), separated by regular offsets (w. 1 m circa) have been found. The sizes of these walls are respectively: 6.64 m; 7.84 m and 7.97 m.
During the cleaning of this sector a squared tower (4x4 m), not singlet out by the AFSM mission, has been unearthed. The tower (A97), placed in front of the wall M223 at 2.80 m of distance from it, has its western face lined up with the offset of M221. The tower shows more or less the same sizes of the other squared tower A61, raised on the other side as to the city gate complex.
The two towers appear almost quite symmetric, looking the northern side of the city.
This area was completely covered by a big accumulation (US215), mainly constituted by the dumps discarded by AFSM and IMTO missions, mixed with wind deposit and destruction layer.
The removed accumulation US215 produced a large amount of different findings, obviously out from their original stratigraphic context: pottery shards, bronze objects (among which a big hemi-cylindrical element MB456, a fragment of mirror MB453, a finger-ring MB472, a fragment of vessel rim MB440), fragments of soft-stone vessels, some stone daily use tools, four bronze coins (Co401, Co402, Co404, Co422), animal bones and a large amount of marine shells.

North-eastern corner of the city (trench supervisor A. Lombardi)

This sector was completely covered by an enormous accumulation of dumps, discarded by the AFSM mission, and appeared separated from the other western accumulation (US215) by a kind of big groove, probably created by the rain water. The digging was starting from the top and, at the same time, from the western limit, along the above mentioned groove.
The upper thick layer (US223) was constituted by very soft earth of dumps, mixed with aeolian deposit, with a large amount of stone masonry blocks of various dimensions. The US223 produced a fair amount of pottery shards, few stone objects (among which a relevant limestone inscribed weight, S1087), three bronze coins (Co406, Co423, Co424), animal bones and marine shells. This layer covered completely the city eastern corner, reaching the low level, especially in front of the northern side of the easternmost big structure.

The accumulation US223 covered a very hard destruction layer (US227), constituted by the collapsed walls and internal filling of the two big structures singled out by the AFSM mission as III M19 and III M22-M23. The destruction layer US227 produced few findings: some pottery shards, three stone daily use tools (S1092, S1093, S1094), a fragment of glass small bottle (G98) and two bronze coins (Co420 and Co421) of medium size, both belonging to the coinage of Yashhur'il Yuhar'ish, son of Abiyasa, *mukarrib* of Hadramawt (series head/eagle, Sedov type 4).
The two imposing structures, as showed by the removed destruction layer US227, were only partially excavated by AFSM mission. In particular the more western one (A102 = III M19), which could be interpreted as big corner tower, was identified only by the digging in its top level. During this campaign the tower has been completely unearthed, until its foundation level on the bedrock (elevation 25.731 on the sea level). The tower is preserved, along its northern face, only for two-three rows of limestone big squared blocks, while the north-western and north-eastern (at the junction with the easternmost structure A103 = III M22-M23) corners are better preserved, with seven/eight rows of limestone big blocks. Its western face has been unearthed only for a small sector, because of the impossibility to remove completely the filling in this point, to assure the stability of the last sector of the city wall, still to be excavated and restored. Fragments of whitish mortar (with small pebbles an red inclusions) were preserved at the junction between the limestone blocks.
The tower A102 (8.53x7 m in size), built with regular and big limestone blocks (medium size 65x45x30 cm), shows the usual building technique of the others monumental structures and city walls of Sumhuram: an external regular curtain wall and an incoherent internal filling composed of rough-cut stones of different size, mixed with clay and compact clay mortar. The tower was probably bonded with the city wall and also related to the easternmost structure A103, with which seems to share the masonry at the east corner. So, it is very probable that all those structures (A102, A103 and city walls) belong to the same constructional phase. But, this hypothesis has to be verified after further investigations in the future excavation campaigns.
In its short description, F.P. Albright speaks about an extramural structure (III M19), with the interior divided into several rooms, connected in function with other intramural rooms (VI B16 and VI E19) of the north-eastern corner of the city. But, clearly, the scholar had singled out only the top of this structure without excavating the base of the tower.
The other monumental structure A103 (= AFSM III M22-M23), projecting of 4.60 m as the northern limit of A102, was almost completely unearthed by the American mission, with the exception of its western face, at the corner with A102, which was covered by the same destruction layer US227. The corner between the two towers has been completely unearthed during this campaign and appears well preserved. Clearly, the masonry of A103 is leaning to A102, that indicates a sequence in the constructional work; anyway the two towers could belong to the same building phase, because of the allignment of the rows of the limestone blocks at their bases.
The northern face of A103 (w. 5.40 m) has been simple cleaned by the filling US223. In this face the limestone blocks are very imposing, reaching a size of 1.30x0.50x0.60 m, and showing a particular triangular shape, realised probably to facilitate the masonry work.
The massive structure A103, interpreted by F.P. Albright as possible "foundations of burial vaults", was most probably an additional defence tower, built also to better support the north-eastern corner of the city wall. Its internal recess (a sort of blind corridor of 0.80 m of width, unearthed by the AFSM mission) could have been realised to lighten the structure and make it more stable.

Area A

City Gate (trench supervisor A. Lombardi)

Inside the city gate, already investigated during the previous IMTO missions, the internal of the tower A6 has been completely cleaned from the collapsed stones and the internal filling of the eastern wall M3. In addition, in A1, along the northern face of the wall M12 and in the corner with M3, a deep sounding has been excavated, until the foundations of the walls. In the narrow trench open along M12 the bedrock has been reached (23.17 m on the sea level). The wall M12 has its foundations on the bedrock, that in this part is deeper than in the western part of the city gate, where is placed the defence tower A47.
In the above-mentioned trench, starting from the top, the last floor (US17), already singled out during the 00A campaign, has been cleaned again. This floor covered an occupation level of about 25 cm of thickness, which ended on another floor, compacted over a rough-cut stones levelling. The filling US228 was composed by compact greasy loam, with whitish inclusions, animal bones and charcoals.
After the removal of the stones connected with the floor US228, a soft filling (US229), of a thickness of about 70 cm, mixed with chips of stones, has been found. In the last part of the US229 has been found a fair amount of shards, animal bones and charcoals. The US229 ended on the level of bedrock. It seem probable that the remains of occupation, found in the final part of the filling, are related with the construction of the wall, while the upper part of the stratum could be a levelling filling, intentionally made to reach the level of the other masonry structures of the city gate, before the construction of the floor US228.
Finally, has been verified that the completely collapsed wall M3 was founded at the level of the last floor US17 and therefore has been built in a following phase than M12. Nevertheless, the precise relations between the wall M3 and the tower A6 have to be still clarified, after the demolition of the wall M3 for the process of restoration.

Room A98 (trench supervisor A. Lombardi)

The three rooms A98, A99 and A100 are placed along the city walls M14, M220, M221, which constitute also the northern walls of the rooms itself.
A98 (= AFSM III O1), placed at the junction between the city walls M14 and M220, and already partially investigated by the AFSM mission, has been cleaned in its northern half from the big amount of collapsed stones and filling. Starting from the north-western corner of the room, the upper filling (US219), accumulated after the AFSM excavation, has been removed. The filling consisted of very soft earth of wind deposit, mixed with small stones, some shards, marine shells and animal bones. Inside the US219 also four bronze coins (Co407, Co408, Co410, Co416) and a bronze small plaque (MB473) have been found.
After the removal of the US219 it was possible to see a separation line (oriented N-S), which probably represents the cut of the AFSM excavation. In fact, the western part of the room was only partially excavated, while in the eastern one a large platform was been reached, which F.P. Albright describes as base supporting a stair. This platform (w. 1.50 m), covered by a thick crust of compacted soft earth, has been again unearthed, while the stone steps were lacking.
Starting from the top of this platform the filling of the room changed completely: the new US220, removed in a small sector of the northern part of the room, was clearly an original, never excavated filling. It consists of compact, dark brown greasy loam, mixed with ashes and collapsed stones. The filling has a thickness of about 75 cm and ends in a floor, cleaned only for a small sector, against the northern city wall M220.
The floor US220 (29.32 m on the sea level) is made out of packed earth, with small charcoals and bones compacted inside. In the corner, between the northern wall and the stair platform, a small fire-place has been unearthed. The fire-place is composed by two roughly worked rectangular and flat stones (*circa* 30-35x20 cm), placed at acute angle. The US220 produced few small findings: a

stone loom-weight (S1059), a rough calcarenite mortar (S1060), a stone polisher (S1061) and a shell bead (Sh289).

Room A99 (trench supervisor B. Bottoni)

The room A99 (AFSM III M2), adjacent to the room A98 and, in according to Albrigth, part of the same building, has been cleaned in its northern half. A thick accumulation (US217), composed of earth, collapsed stones and pebbles, clearly lodged after the AFSM excavation, has been removed until 29.25 m on the sea level. The US217 produced only a decorated and red coloured fragment of a probable squared incense-burner (S1064) and a *chlamys townsendi* shell (Sh288).

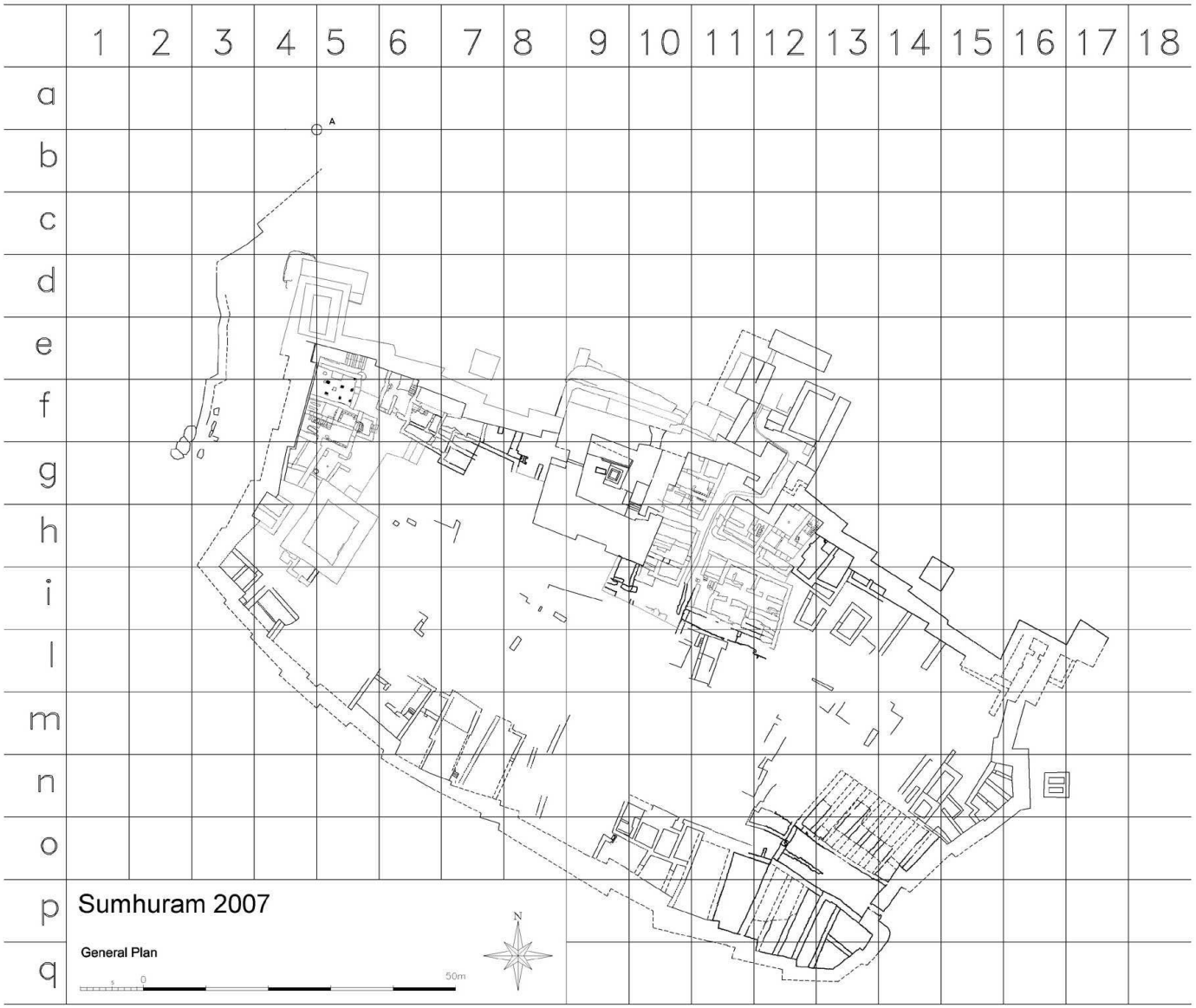
Rooms A100-A101 (trench supervisor A. Lombardi)

The room A100 (AFSM III M4), with its long side parallel to the city wall M221, has been almost completely excavated. In fact, the AFSM mission seems to have limited its work to the identification of the room's perimeter walls. The room A100 (5.90x1.65 m in size) is delimited in the northern side by the city wall M221, in the south by the wall M224 (w. 70 cm), in the east by the offset of the city wall M221, while its western perimeter wall M225 is almost completely collapsed. After the removal of the upper filling US218, inside which an almost complete green glazed jug has been found (US218, 3), a partition wall (M226), of 60 cm of width, divides the room in two small rooms: A100 (in the eastern half) and A101 (in the western half).
The two small rooms were filled by different layers: in A100 the US222 (th. about 80 cm), consisting in compact loam, mixed to collapsed stones, animal bones (especially of whale), marine shells and pottery shards, has been removed. The occupation filling US222 ended in a very compact floor with fragments of whitish plaster, traces of burning and big whale bones.
The filling US222 produced few findings: two bronze coins (Co405 and Co411), a glass bead (G97), some daily use stone objects (S1062, S1065, S1082) and two *chlamys townsendi* shells (Sh291, Sh292).
In the room A101 the occupation filling US224 (th. about 50 cm), composed by loam mixed with ashes and charcoals, has been removed. The filling covered a very well preserved and compact floor (US224floor), carefully plastered in its western part. Over the floor has been found two complete vertebras of whale, well worked and refined, used as room furniture (probably as seats) and a third fragment of whale vertebra. The US224 produced a fair amount of pottery shards, animal bones and a large amount of marine shells. In addition, a bronze coin (Co412), a singular bone comb (B49), a loom-weight (S1071), two whetstones (S1069 and S1072), a handstone (S1070) have been found inside the filling, near the floor.
The excavation has continued in the eastern room A100, where a thick stratum (th. 45 cm) of crumbly reddish earth, completely backed by fire, has been removed (US225). Inside the US225 very few findings has been found: some shards, animal bones, marine shells and a coin (Co413). The filling US225 could be related with a big furnace, being clearly present also under the floor US224. In fact, the partition wall M226 has its foundation under the floor US222 and the two rooms (A100 and A101) become again a single room (A100). In other words, the two small rooms were related only with the occupation level of US222 and US224.
After the complete removal of the US225, there is a clear stratigraphic separation, constituted by a light brown grey level, that covers a deep filling of big and medium size superimposed roughly worked stones (US226). Those stones fill up the entire room A100 and it is leaning on the city wall M201. Three rows of stones have been removed, until 29.42 m on the sea level, but the filling US226 continues down, also in the western part of the room A100, still to excavate. This stones filling appears intentionally made and probably was related to the construction of the city wall more than the occupation levels of the room A100. In fact, the southern perimeter wall of the room

(M224) has its foundations more or less at the same level of the beginning of the US226 (30.17 m on the sea level). Inside the stone filling US226 two bronze coins (Co414 and Co415) and two small bronze objects (MB464 and MB465) have been found.

Area B (trench supervisor B. Bottoni)

In order to complete the work of the last campaign in the area of the storehouses, the room A88, already excavated by the American mission (AFSM IX K3), has been cleaned from the accumulation of wind deposit and from the underlying compact crust (US216), which covered the room's floor. This unearthed floor is well preserved and it is completely covered by whitish plaster.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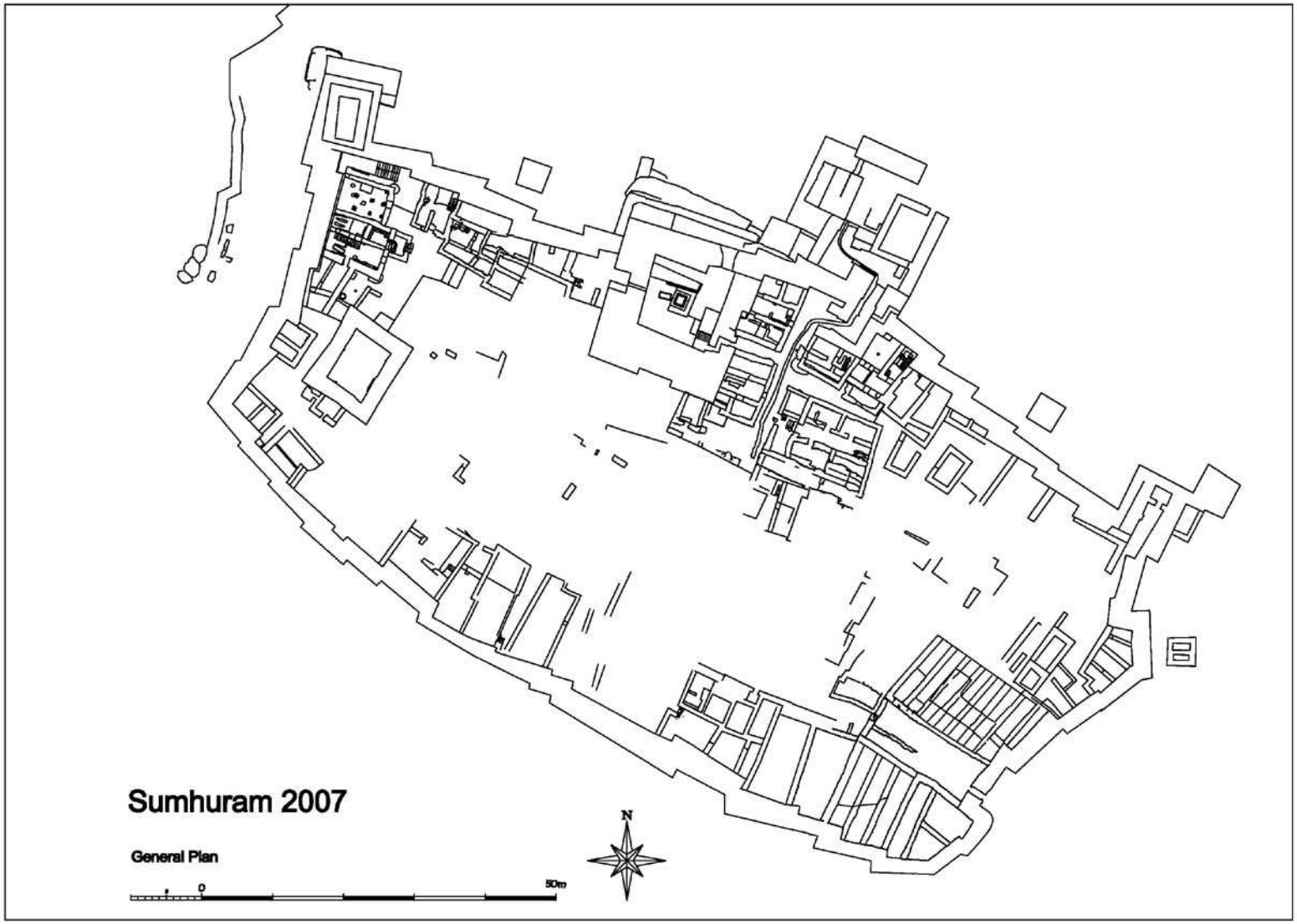
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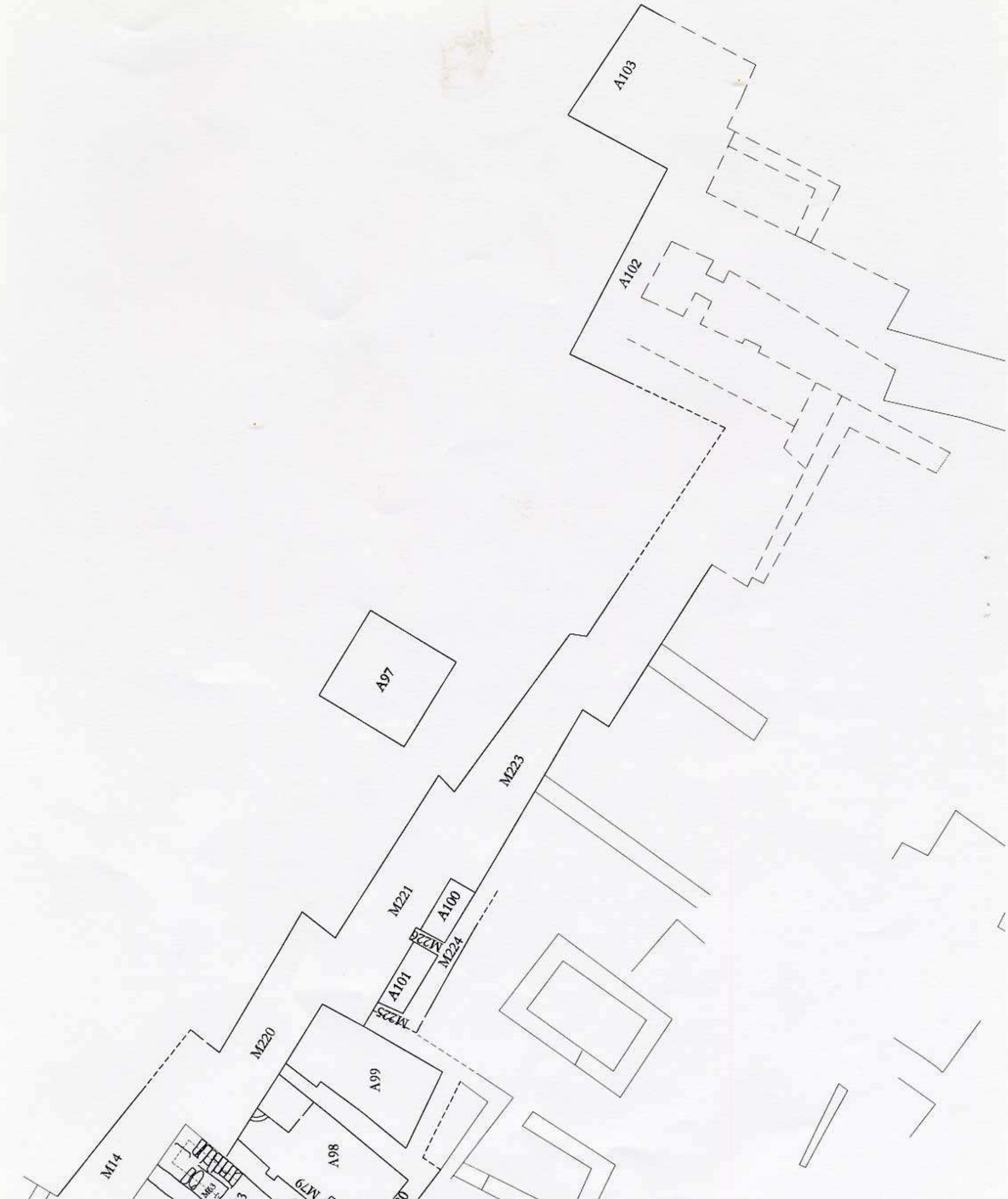
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A102
A97
M223
M221
A100
M226
M224
A101
M225
M220
A99
A98
M14
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M60
M80
M62
A33
M69
BA4
A32
M4
A36
M70
M82
M81
M101
M77
A40
A37
M70
M102

Fig. 1 - The north-eastern sector of excavated city walls with the tower.

Fig. 2 - The tower A97, from the north-east.

Fig. 3 - General view of the two big structures, from the north-west.

Fig. 4 – Particular of the corner between A102 and A103.

Fig. 5 – The remains of the northern face of the tower A102.

Fig. 6 – The northern side of the structure A103.

Fig. 7 – The deep sounding along the wall M12.

Fig. 8 – General view of the room A101, from the east.

Fig. 9 – The room A101 with the plastered floor and the whale vertebras.

Fig. 10 – Area of the storehouses: the room A88.

Object Index Card

Registration Nr. SUM07A; US218,3		
Provenance Area A, A100		
Definition Glazed jug		
Material Baked clay	**State of preservation** Found in 17 fragments	**Measures** h. 29 cm rim diam. 10.5 cm base diam. 10.5 cm max. diam. 22.5 cm th. wall 1 cm
To be restored	**Preserved part** Almost complete	

Description

Almost complete green glazed jug, lacking only of the rim. The strap handle (w. 4.2; th. 1.2 cm) has two large and flat grooves in the centre. Two band of three horizontal, parallel and flat grooves are placed at the shoulder and around the maximum circumference. The green glazing (Munsell Gley 1 4/5G) covers almost all the external surface, starting at 5 cm from the base.
This type of glazed jug is originating from the Gulf area.

Responsible A. Lombardi	**Date** 02.03.07

Object Index Card

<table>
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SUM07A; US215, 21

S1050</td><td colspan="3">   </td></tr>
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Area A7
Squares h-14</td><td colspan="3"></td></tr>
<tr><td>Definition
Small pillar</td><td>State of preservation
fair</td><td rowspan="2">Measures
l. 9.9
w. 3.2
h.
th. 3
diam.</td><td>Shape
rectangular</td></tr>
<tr><td>Material
limestone</td><td>Preserved part
fragment</td><td>Section
slightly convex</td></tr>
<tr><td colspan="4">Description

Small square pillar, broken at the two ends. The fragment is well refined on two contiguous faces, while the others two are roughly worked and blackened (probably by bitumen). The refined and polished faces preserve two superimposed raised bands (h. 0.8 cm) at one of its ends and just one (only on the lateral face) on the other end.
The fragment probably was part of the base of a composite incense burner, in which the cubic censer was supported by some pillars. (Cfr. Albright 1982, cat. 111, p. 98; fig. 51).</td></tr>
<tr><td colspan="2">Responsible
A. Lombardi</td><td colspan="2">Date
6.02.07</td></tr>
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Object Index Card

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SUM07A; US223, 14
S1087</td><td colspan="3" rowspan="3">  </td></tr>
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Area A7; i15</td></tr>
<tr><td>Drawing code Nr.</td></tr>
<tr><td>Definition
Stone weight</td><td>State of preservation
good</td><td rowspan="2">Measures
l.
w. 4.7
h. 6.7
dp. 3.6
wg. 165 g.</td><td>Shape
trapezoidal</td></tr>
<tr><td>Material
limestone</td><td>Preserved part
complete</td><td>Section
rectangular</td></tr>
<tr><td colspan="4">Description
Trapezoidal-shaped weight, rounded at its corners. On the top a low, trapezoidal element (w. 3.2; dp. 1.9; h. 1.6) furnished with hole (d. 0.6). In the frontal large face is readable an incised SA inscription, not well realized. We can read the name of the god S¹yn, written from left to right. All the surfaces are well polished.</td></tr>
<tr><td colspan="2">Responsible
A. Lombardi</td><td colspan="2">Date
20.02.07</td></tr>
</table>

IMTO – Italian Mission to Oman

University of Pisa

Restoration and Consolidation activities
TECHNICAL REPORT

February - March 2007

(SUM07A)

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PREFACE

In relation to the archaeological campaign hold by the Italian Mission to Oman (IMTO) in the site of Khor Rori from January the 20th 2007 to March the 15th 2007, and managed by prof. Alessandra Avanzini of the Department of Ancient History of the University of Pisa, structural restoration interventions were programmed on collapsing or collapsed masonry walls, with the aim of achieving a satisfactory level of safety to permit further studies and the opening of the site to public visitors.
The programmed restoration interventions mainly consisted in:

- excavation of the north external side of the site;
- restoration of wall M14;
- restoration of the A97;
- restoration of wall M220;
- restoration of wall M221.

Restorations have been done following the same proceedings of the past campaigns, according to the UNESCO issues.

1. GENERAL DESCRIPTION OF THE INTERVENTION

1.1 Excavation phase

The intervention began on January the 20th with a careful and accurate inspection of the north area of the site, starting from wall M14 and proceeding from its west side towards the area delimited by pickets.
This first phase of intervention has been done under the supervision of the archaeologist Alessandra Lombardi.
The western side of wall M14 was well visible and also in a good state of preservation, but it was almost completely recovered by archaeological excavation's detritis not allowing to know its exact position and development. Consequently, the first part of the intervention consisted in removing the earth in front of the wall, in order to look for the exact position of wall M14.
During this phase, on January the 21st, the bed rock under wall M14 has came to light.
On January the 22nd and 23rd it has appeared a series of stones which seemed to be lined and another part of wall (M220), but withdrawn to wall M14. This part was in a very bad state of preservation and in the area where the corner is supposed to be located, a landslide and a climbing plant caused some difficulties in the intervention. Going on in the digging phase, it has emerged another series of stones outlining the development of the following wall. Under this series, it has been noticed another series of lined stones on the left side of the wall, and underneath a whole line of stones with part of plaster.
In the meantime, and unexpectedly, on January the 17th, it has appeared the tower A97, located about 1 m in front of wall M221.
On February the 3rd, behind the tower, the prosecution of wall M223 has been found: it has appeared in a good state, well preserved and separated in two parts by a corner. On its eastern side, M223 seemed to have some detached stones, so that it has been necessary, before its restoration, to wait for the archaeological excavation backwards to lighten the internal earth pushing on the wall.
On the other hand, the right part behind the tower was better preserved, because of the retaining function of the earth between the tower and the wall itself.
At the end of the research, on the eastern side of wall M223, it has been found another part of the wall in a very bad state of preservation, but laying outside the programmed area of intervention.
At the end of this phase, the real development layout of walls M14, M220, M221, M223 and tower A97 was evident, so that it has been possible to start the restoration intervention and, at the same time, to balance the internal pushes before the future archaeological excavation.

1.2. Restoration of wall M14

Wall M14 is a masonry structure belonging to the city complex. It is characterised by a rectangular footprint, with a longer side of 8,2 m and a thickness of 2 m; the height varies along its borders, showing an average value of around 3 m, measured from the supposed bedrock which has been found beneath. The western side of the wall had already been discovered and was also in a good state of preservation, at least up to a certain height.
The eastern side was still covered by earth, and, once discovered, showed a pretty bad state of preservation.
However, during the restoration, it has been tried not to change the ancient building technique and the stones arrangement, excepted only for those areas where some problems of stability and duration have been noticed.
So, the programmed intervention has involved static, historical and aesthetical aspects, since it was aimed to put the wall in safety conditions, beside to endow it with a pleasant appearance, consistent with the integer part of the wall itself and with the other masonry structures in the site. To attain this purpose, a first phase has been prescribed, in which the damaged parts of the wall have been dismantled, while the integer ones have remained unmodified. Some removed stones have been numbered by the mean of a chalk stick and then heaped nearby, in the outlook of their future usage during the rebuilding phase. As this operation has been fulfilled, the wall has been rebuilt up to a level which constitutes an authentic estimation of the minimal height the wall featured in the past, using the collapsed stones removed before. Prior to the wall rebuilding, a narrow geo-textile strip has been applied on the external surface of the upper face of the old stones, to remark the separation between the unmodified ancient masonry and the new part introduced with the present restoration.
Then, small stones and lime mortar have been employed in rebuilding the inner part of the wall, with the only difference that the mortar has been done with no colours.
To realize the upper closure of the wall, some stones have been put in an irregular arrangement and linked together with mortar (so called “beautification”), with both the aesthetical purpose of making the wall looking similar to the others in the site and the technical purpose of making the wall waterproof.
At the end of the eastern side of wall M14, the corner between M220 and M14 itself showed a significant collapse, so that it has been decided not to refine the corner with a vertical wall but to arrange it with the same technique used to realize the upper closure, so that the collapsing phenomenon underwent by this corner will be more evident.

1.3. Restoration of tower A97

Tower A97 is located in front of wall M223 and it is characterised by an approximately square footprint of 4,1m x 4,2 m. Its north wall was completely destroyed instead of the south one which showed a very good state of preservation.
The two side walls (both eastern and western one) were characterised by some tilted or missing stones (especially towards the northern side) while they were well preserved towards the southern side. The restoration started from the removal of the earth that submerged the northern part of the tower, while the back part has been partially recovered with the earth coming out both from the tower and from wall M223, in order to allow us to have an earth support for both continuing the work of unearthing the wall standing in the back (M223) and to complete the works on the tower itself. Then, the outer parts, the filling and the upper closure have been realized with the same technique used for the other walls, and already described in § 1.2. At the end, some more earth has been removed between the southern side of the tower and the wall M223, arranging two light slopes shoaling towards the eastern and the western sides of the tower, in order to facilitate the water run-off and to give a more pleasant appearance to the embankment which retains wall M223.

1.4. Restoration of wall M220

Wall M220 is located between M14 and M221, and it’s characterised, as the adjacent walls, by a rectangular footprint, with a longer side of 6,6 m (the external one) and a thickness of 2,5 m; the

height varies along its borders, showing an average value of around 3 m, measured from the embankment below the wall.
The restoration of M220 started while the archaeologists were excavating the rooms in the back of the wall, in order to lighten the earth pushing on the back side of the wall.
The restoration technique used here has been lightly different from the above described one used in M14 restoration, in the sense that the intervention has not consisted of two separated phases (a dismantling phase and a rebuilding one), but the two phases have proceeded at the same time, mainly because of the bad state of preservation showed by the wall.
At first the work has started with the removal of the earth that covered the lateral parts of the wall leaving the earth above the central part. Then it has gone on with the contemporary reconstruction of the lateral parts and the removal of the earth in the central part and its consequent reconstruction.
This technique has been used to preserve the wall from further collapses of the landslides on the top.
At the end of the reconstruction of the outer region of the wall, it has started the intervention of "beautification" on the top of the wall, in order to make the wall waterproof and to endow it of a better aesthetical aspect.

1.5. Restoration of wall M221

M221 wall is located between M220 and M223. As the above described walls, it is characterised by a rectangular footprint, with a longer side of 7,8 m (the external one), and a thickness of 2,5 m; the height varies along its borders, showing an average value of around 3 m, measured from the embankment below the wall.
The restoration of M221 has been done following the same technique and the same procedures used for the restoration of M220, and already described in § 1.4.

2. WORKS ACCOUNT

2.1. Restoration of wall M14

2.1.1. Used materials

As in the past campaigns, walls have been rebuilt using local stones and a particular mortar mixture.

- *Mortar mixture*. The mortar mixture has been determined by making some tests with different proportions of colour and lime in order to obtain the right colour. The chosen mixture has been essentially determined by observing the outcomes of the mixtures previously employed in the site of Khor Rori. On the base of such assessments, it has been decided to give up the cement component and neither to employ natural earth withdrew from the ground, according to the UNESCO issues. This because many mixtures containing those elements showed in the past sensible colour variations, reasonably as a consequence of chemical reactions which led to formation of mineral salts. In this aim, artificial brownish sand, produced crushing local stones, was selected; and the 1:4 mix proportion was regarded as the most suitable in this case.

After these tests, the natural colours proportion has been set to: 1 part of yellow, 0,5 part brown, 20 parts of lime. So the standard mixture was made with four buckets of sand and one bucket of the previous mix of lime and colours.

- *Stones arrangement.* The masonry units were withdrawn partially from the ones resulting from the dismantling phase, and partially by the other heaps present in the site.

- *Surface refinement*. After rebuilding the wall for a certain length, the external surface was adjusted filling carefully the leaks between the stones with mortar, and then, as soon as the mortar had became enough consistent, smoothing the joints with soft brushes. Finally, the stones external faces have been cleaned with sponges and clear water.

2.1.2. Dismantling phase

This phase has been accomplished on February the 4th. The crumbled material has been removed starting from the top of the wall, by means of hand instruments. Some stones forming the wall body

have been heaped nearby, in the outlook of a following usage during the wall reconstruction. No stone has been removed from those parts of the wall featuring structural integrity and a proper masonry arrangement.

2.1.3. Rebuilding phase

On February the 4th, after the removing phase had been terminated, the rebuilding operations on the wall M14 have been started and they have been terminated on February the 13th with the completion of the upper closure. The reconstruction works mainly concerned the following issues:

- *Outer sides*. They have been rebuilt on the wall outer structures remained essentially undamaged over the centuries, which had been saved in the dismantling phase, and they have been realized according to the abovementioned procedure, decided through the wall sampling. A film of geotextile has so been posed in the first mortar joint to separate the new rebuilt part of the wall from the old one. At the end 5 lines of stones have been rebuilt.
- *Inner part*. The wall body has been rebuilt using small stones and mortar, the latter made by using a different kind of sand then the one used in the external sides and with no colours.
- *Upper closure*. It has been realized arranging medium and small stones irregularly, always in order to reproduce the appearance shown by the tops of the other walls in the site. At the end, every hole among the stones has been closed with mortar, and the joints have been then smoothed with soft brushes, as usual.

On February the 1st, during the reconstruction of wall M14, the "beautification" of the corner between M14 and M220 has been started. The refinement of this corner went on, in different phases, until March the 12th, at the same time with the removal of the earth in front of the wall, which has been done by using the motor scraper.

2.2. Restoration of the tower A97

2.2.1. Used materials

The same materials and the same procedures described in § 2.1.1. have been used.

2.2.2. Dismantling phase

The restoration works of the tower A97 began on January the 29th and finished on February the 28th with the accomplishment of the upper closure.

The dismantling phase started from removing the stones in bad state all around the sides of the tower until reaching those parts of the wall featuring structural integrity and a proper masonry arrangement. The crumbled material has been removed starting from the top of the walls, by means of hand instruments. After that, it has been lightened the filling of the tower removing earth and stones, in order to allow the connection between the walls in the corners, with the aim of making the structure more stable. All these operations have been terminated on February the 5th.

2.2.3. Rebuilding phase

On February the 7th, after the removing phase had been terminated, the rebuilding operations on the tower A97 have been started and they have been terminated on February the 28th with the completion of the upper closure. The reconstruction works mainly concerned the following issues:

- *Outer sides*. They have been rebuilt on the wall outer structures remained essentially undamaged over the centuries, which were saved in the dismantling phase, and they were realized according to the abovementioned procedure, elaborated through the wall sampling. A film of geotextile has been posed in the first mortar joint to separate the new rebuilt part of the wall from the old one. At the end 6 lines of stones have been rebuilt in the northern side, and 1 line in the southern one, while the lateral parts have been arranged with a slight slope shoaling towards the northern side, in order to endow the tower with a more pleasant appearance.

- *Inner part*. A part of the wall body has been removed and then has been rebuilt using stones and mortar, the latter made by using a different kind of sand then the one used in the external sides and with no colours.

- *Upper closure*. It has been realized arranging stones irregularly, in order to reproduce the appearance shown by the tops of the other walls in the site. At the end, every hole among the stones has been filled with mortar, and the joints have then been smoothed with soft brushes, as usual.

2.3. Restoration of wall M220

2.3.1. Used materials

The same materials and the same procedures described in § 2.1.1. have been used.

2.3.2. Dismantling and rebuilding phases

The restoration of wall M220 began on February the 5th with the removal of the earth on the lateral parts of the wall, leaving the earth above the central part. At the same time, the archaeologist Alessandra Lombardi started the works of excavation in the rooms behind the wall, in order to lighten the earth pushing on the back side of the wall. The crumbled material has been removed starting from the top of the wall, by means of hand instruments. The stones forming the wall body have been heaped nearby, in the outlook of a following usage during the wall reconstruction, while the earth has been completely brought away. No stone has been removed from those parts of the wall featuring structural integrity and a proper masonry arrangement. On February the 13th the removal of the stones has been terminated and it has started the reconstruction of the outer part of the wall that has gone on until February the 25th. The work started from the reconstruction of the western and eastern side of the wall with three uncompleted lines and the contemporary removal of the earth in the central part of the wall. In this way the risk of collapses has been reduced and it has been possible to go on with the reconstruction. After that, some stones have been placed in the centre and the lines have been completed. It has then been possible to go up with the positioning of the stones and the refining of the mortar joints, up until the wall has been completed. At the end of the reconstruction the wall shows 7 rebuilt lines separated from the old part of the wall by a geotextile strip.

After this phase, it has been started the “beautification” in the upper part of the wall, until March the 6th.

2.4. Restoration of wall M221

2.4.1. Used materials

The same materials and the same procedures described in § 2.1.1. have been used.

2.4.2. Dismantling and rebuilding phases

The restoration of wall M221 began on February the 13th with the removal of the earth on the lateral parts of the wall, leaving the earth above the central part. At the same time, the archaeologist Alessandra Lombardi started the works of excavation in the rooms behind the wall, in order to lighten the earth pushing on the back side of the wall. The crumbled material has been removed starting from the top of the wall, by means of hand instruments. The stones forming the wall body have been heaped nearby, in the outlook of a following usage during the wall reconstruction, while the earth has been completely brought away. No stone has been removed from those parts of the wall featuring structural integrity and a proper masonry arrangement. On February the 14th the removal of the stones has been terminated and it has been started the reconstruction of the outer part of the wall that has gone on until February the 27th. The work has started from the reconstruction of the western and eastern side of the wall with three uncompleted lines and the contemporary removal of the earth in the central part of the wall. In this way the risk of collapses has been reduced and it has been possible to go on with the reconstruction. After that, some stones have been placed in the centre and the lines have been completed. It has then been possible to go up with the positioning of

the stones and the refining of the mortar joints, up until the wall has been completed. At the end of the reconstruction the wall shows 7 rebuilt lines separated from the old part of the wall by a geotextile strip.
After this phase, it has been started the “beautification” in the upper part of the wall, until March the 8th.
On March the 11th and 12th one last intervention on the wall has been done. Indeed, while digging down in front of the wall, three tilted stones have been found. So, they have been dismantled taking care not to compromise the stability of the other stones. Then a geotextile strip has been posed in order to highlight the intervention and the stones have been replaced and fixed with mortar. At the end, the stones and the mortar joints have been smoothed with soft brushes, as usual.

3. ADDITIONAL WORKS

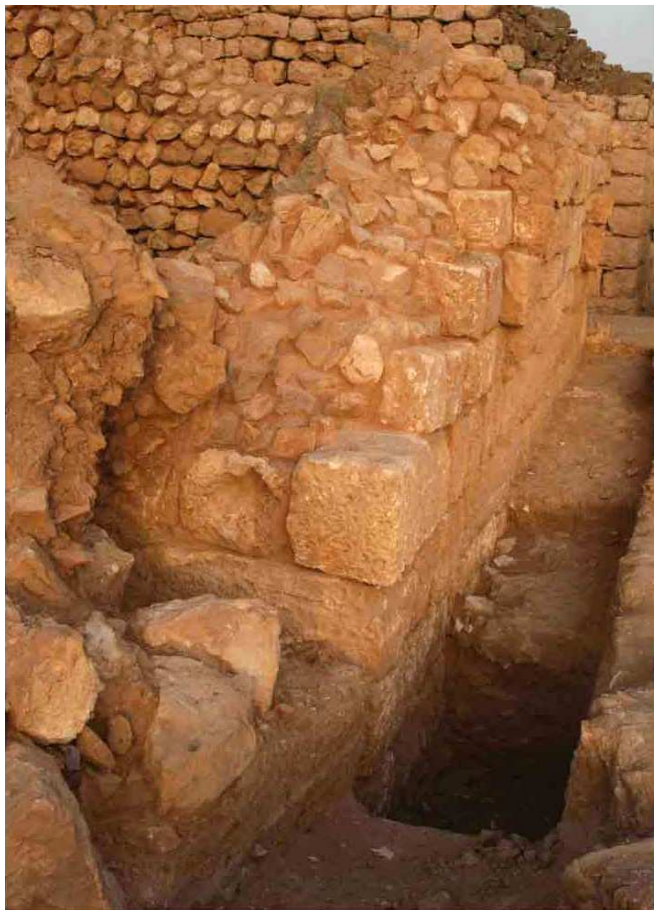
Some additional works have been programmed during this campaign.
On February the 6th a restoration intervention on the corner between M12 and M3 has begun but it has been stopped on February the 7th because of archaeological reasons. The intervention has restarted on February the 22nd and, in agreement with the archaeologist Alessandra Lombardi, only few big stones of wall M12 have been replaced and then covered with small stones and mortar (“beautification”) with the same technique used for the others walls. When all the abovementioned works have been successfully completed, some “cleaning” interventions have been programmed: the earth and the stones remained in front of the walls after the works have been removed, and all the working instruments have been put to their place.

Salalah, March 15th 2007

The staff of the Department of Structural Engineering – University of Pisa:
Prof. Mauro Sassu (coordinator), Luca Angelini, Chiara Cei, Alessandro Gioeli,
Maria Francesca Mollica, Federico Rosa, Alessandro Soru.

Corner of Wall M12 before the restoration

Corner of Wall M12 before the restoration



M14 before restoration

M14 after restoration

M220 before restoration

M220 after restoration

M221 before restoration

M221 after restoration

Before restoration

North side view

West side view

Upper South Eastern side view

After restoration

North side view

West side view

Upper South Eastern side view

Botanical Report

M. Raffaelli, M. Tardelli, S. Mosti
Tropical Herbarium Studies Centre
University of Florence
Ahmed Al-Awaid,
Office of the Adviser of H.M. the Sultan for Cultural Affairs

The main points of our program in Dhofar were: 1) the study of the plants of *Boswellia* (frankincense tree) located in the Wadi Doka Natural Park in order to continue the monitoring of the middle-aged and of the oldest plants of the Park, in order to study the annual growth increase, the flowering and fruiting period, the seedling renewal, the health conditions and the interventions of safeguard. 2) the study of the growth of the seedlings of *Boswellia* planted in the "transplanting area" of the park. 3) The identification of the plants of the Al-Balid Botanical Garden. For each plant we gave the scientific latin name; we also increased the number of the plants of the Garden collecting new wild plants from the territory around Salalah.

First point of the program: Wadi Doka Natural Park

For the oldest and heaviest *Boswellia* plants we suggest the following safeguard interventions:

1) Root protection

It is necessary to cover with stones the bases of the trunks and the big superficial uncovered roots. The plants of the Park grow on a gravely and detrital sediment and their roots are superficial and tend to develop horizontally. In occasion of sudden meteoric events, like floods or wind storms, roots get uncovered. This causes instability and suffering of the plants and, consequently, their fall and death.

2) Damage caused by browsing and tree-cutting

Other safeguard interventions aims to limit the effects of dromedary and goat browsing, stop the tree-cutting for fire-wood, and the use of foliage for fodder.

The animals mainly browse on the young annual shoots; this activity impedes the development and growth of the shoots so that the plants remain of the same size year after year and assume a withered appearance with shortened and enlarged branches carrying only few leaves. Browsing also causes the elimination of the young seedlings preventing the natural regeneration of the plants.

Tree-cutting for fire-wood and the use of foliage for fodder represent further activities that limit the natural growth of the plants.

3) Blocking the accesses

In the Park the major concentration of *Boswellia* plants grow in the wadi bed. To preserve these old plants it is necessary to prevent the access to animals.

Final remark

The *Boswellia sacra* populations of the Wadi Doka Natural Park can be safeguarded with measures intended to prevent animal browsing, tree cutting for firewood, and leaf use for fodder production. The monitoring of the oldest and heaviest plants is necessary, especially aimed to earth the roots that get uncovered and to control the presence of infestations and parasite infections. Many of the *Boswellia* plants of the Wadi Doka Park are unique to Dhofar in behalf of their imposing size and therefore form a naturalistic heritage that should be safeguarded and preserved also in the future.

Second point of the program: Control of the transplanting area of the Park

Another point of the program was the visit and the control of the transplanting area of the Park, where three thousands of *Boswellia* seedlings were planted in the last two years.

In February 2007 (during our visit), the transplant intervention showed a positive result of over 75-80% .The young seedlings had reached a 30-80 cm height; they had new ramifications and abundant new leaves. Some plants were up to 80-90 cm tall, with numerous and enlarged basal ramifications (with branches up to 3-4 cm in diameter), and abundant production of new shoots and leaves.

Final remark

The observations on the annual growth increases of the seedlings of *Boswellia*, after the fencing, are the evident proof that grazing is one of the principal causes of plant degradation. The rapid growth of the *Boswellia* seedlings in the fenced area confirms the good natural regenerative capability of the plant.

Third point of the program: Al Balid Botanical Garden

We prepare a list of the scientific names of plants actually planted in the Garden. The plants are about 161 planted in 37 rows from row 1 to row 37. The order of the rows goes from west to east and the plants in each row go from left to right.

NI: means “not identified plant” because leaves, flowers or fruits are absent.

Row 1

Euclea schimperi (A.DC.) Dandy

Blepharis dhofarensis A.G. Miller

N.I ?Delonix

NI ? Olea

N.I: no leaves, no flowers, no fruits

Anogeissus dhofarica A.J. Scott

Row 2

Ziziphus spina-christi (L.) Willd.

Cissus quadrangularis L.

Sarcostemma vicinale R. Br.

Aloe dhufarensis Lavranos togheter **Aloe inermis** Forssk. and **Desmidorchis** sp. (**Caralluma**)

Row 3

Euclea schimperi (A.DC.) Dandy

Blepharis dhofarensis A.G. Miller

N.I ?Delonix

NI ? Olea

Nanorrhops ritchieana (Griff.) Aitch.

Anogeissus dhofarica A.J. Scott

Row 4

Cordia perrottettii Wight

Boswellia sacra Flueck.

Jatropha dhofarica R.-Sm.

Bentia fruticulosa Rolfe

Ficus lutea Vahl

Adenium obesum (Forrsk.) Roem. et Schult.

Row 5

Euphorbia cactus Ehrenb. ex Boiss.

Dracaena serrulata

Sansevieria ehrenbergii Schweinf. ex Baker

Row 6

Cordia perrottettii Wight

Boswellia sacra Flueck.

Jatropha dhofarica R.-Sm.

Bentia fruticulosa Rolfe

Ficus lutea Vahl

Adenium obesum (Forrsk.) Roem. et Schult.

Row 7

Euclea schimperi (A.DC.) Dandy

Gossypium stocksii Masters

Blepharispermum hirtum Oliver

Lawsonia inermis L.

Adenium obesum (Forrsk.) Roem. et Schult.

Cordia ovalis R. Br. ex DC.

Row 8

Anogeissus dhofarica A.J. Scott

Anogeissus dhofarica A.J. Scott

Anogeissus dhofarica A.J. Scott

Row 9

NI: **Acacia** sp.

Gossypium stocksii Masters

Blepharispermum hirtum Oliver

Lawsonia inermis L.

Adenium obesum (Forrsk.) Roem. et Schult.

Cordia ovalis R. Br. ex DC.

Row 10

NI: **Acacia** sp

NI: ?Delonix

Euphorbia cactus Ehrenb. ex Boiss.

Fagonia luntii (= Fagonia socotrana)

Commiphora habessinica (Berg.) Engler

Woodfordia uniflora (A. Rich) Koehne

Row 11

Euphorbia balsamifera ssp. **adenensis** (Defl.) Bally

Ficus vasta Forssk.

Croton confertus Baker

Row 12

NI: **Acacia** sp

NI: ?Delonix

Ficus vasta Forssk.

Fagonia luntii (= Fagonia socotrana)

Commiphora habessinica (Berg.) Engler

Woodfordia uniflora (A. Rich) Koehne

Row 13

Anogeissus dhofarica A.J. Scott

Euphorbia balsamifera ssp. **adenensis** (Defl.) Bally

Ficus vasta Forssk.

Adenium obesum (Forrsk.) Roem. et Schult.

Acacia sp.

Ziziphus spina-christi (L.) Willd.

Row 14

Euphorbia balsamifera ssp. **adenensis** (Defl.) Bal., together **Sarcostemma vicinale** R. Br.

Cordia ovalis R. Br. ex DC.

Anogeissus dhofarica A.J. Scott

Row 15

Anogeissus dhofarica A.J. Scott

Desmidorchis flavus (= **Caralluma flava**)

Ficus vasta Forssk.

Capparis cartilaginea Decaisne

Acacia sp.

Ziziphus spina-christi (L.) Willd.

Row 16

Maytenus dhofarensis Sebsebe

Maytenus dhofarensis Sebsebe

Maytenus dhofarensis Sebsebe

Maytenus dhofarensis Sebsebe

Row 17

Acacia sp.

Maytenus dhofarensis Sebsebe

Maytenus dhofarensis Sebsebe

Maytenus dhofarensis Sebsebe

Row 18

Maytenus dhofarensis Sebsebe

Maytenus dhofarensis Sebsebe

Maytenus dhofarensis Sebsebe

Maytenus dhofarensis Sebsebe

Row 19

Blepharispermum hirtum Oliver

Blepharispermum hirtum Oliver

Blepharispermum hirtum Oliver

Blepharispermum hirtum Oliver

Row 20

Acacia sp.

Anogeissus dhofarica A.J. Scott

Row 21

Ficus lutea Vahl together **Acacia** sp.

Acacia sp.

Acacia sp.

Acacia sp.

Row 22

Acacia sp.

Acacia sp.

Acacia sp.

Acacia sp.

Row 23

Acacia sp

Lawsonia inermis L.

Row 24

Commiphora gileadensis (L.) C. Chr.

Commiphora gileadensis (L.) C. Chr.

NI: ?Delonix

Blepharispermum hirtum Oliver

Row 25

Jatropha dhofarica R.-Sm.

Jatropha dhofarica R.-Sm.

Aloe vera (exotic, not native in Dhofar)

Acacia sp.

Row 26

Lawsonia inermis L.

Acacia sp.

Row 27

Lawsonia inermis L.

Lawsonia inermis L.

Blepharispermum hirtum Oliver

Blepharispermum hirtum Oliver

Row 28

Euclea schimperi (A.DC.) Dandy

NI:

NI:

Ficus vasta Forssk.

Ficus vasta Forssk.

Row 29

Ziziphus spina-christi (L.) Willd.

Acacia sp.

Lawsonia inermis L.

Row 30

Euclea schimperi (A.DC.) Dandy

Acacia sp.

Lawsonia inermis L.

Blepharispermum hirtum Oliver

Blepharispermum hirtum Oliver

Row 31

Ficus vasta Forssk.

Acacia sp.

Acacia sp.

Lawsonia inermis L.

Lawsonia inermis L.

Row 32

Ficus vasta Forssk.

Acacia sp.

Acacia sp.

Row 33

Acacia sp.

Acacia sp.

NI: ? Delonix

Euclea schimperi (A.DC.) Dandy

NI: ? Delonix

Euclea schimperi (A.DC.) Dandy

Row 34

Euclea schimperi (A.DC.) Dandy

Acacia sp.

Lawsonia inermis L.

Acacia sp.

Acacia sp.

Lawsonia inermis L.

Row 35

Acacia sp.

Lawsonia inermis L.

Lawsonia inermis L.

Row 36

Acacia sp.

Lawsonia inermis L.

NI ?Delonix

Row 37

Lawsonia inermis L.

Euclea schimperi (A.DC.) Dandy

Euclea schimperi (A.DC.) Dandy

Ficus vasta Forssk.

Ficus vasta Forssk.

Adenium obesum (Forssk.) Roem. Et Schult.

During our mission we collected wild plants in the vicinity of Salalah; these plants have been planted in the Botanical Garden.

The most important are:

Adenium obesum

Dracaena serrulata

Desmidorchis adenensis

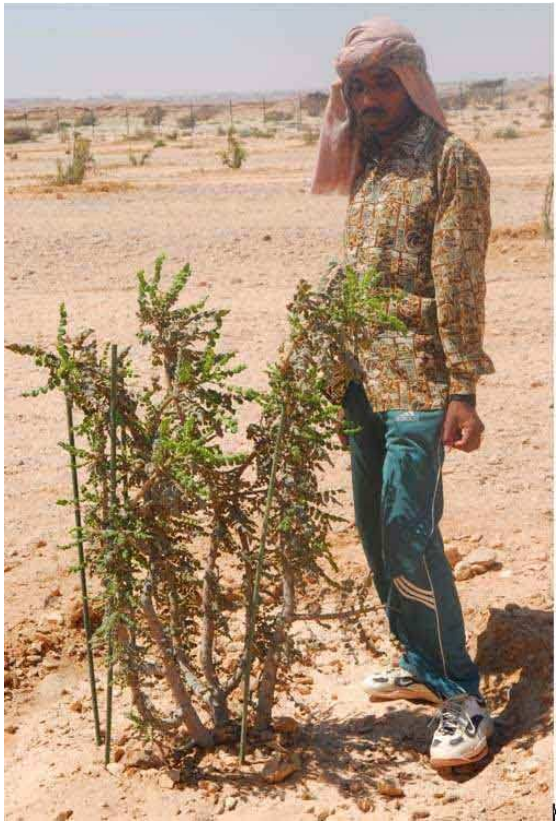
Desmidorchis flavus (Caralluma flava)

Nanorrhops ritchieana

Euphorbia hadramautica

Euphorbia uzmuk

The transplanting area in the Wadi Dowkah Natural Park



A new seedling of *Boswellia* two years old

A view of Wadi Dowkah Natural Park with old *Boswellia* plants

A plant of *Boswellia sacra*, the frankincense tree

A view of the Al-Balid Botanical Garden

Gossypium stoksii (cotton)

Sansevieria ehrenbergii

Fagonia luntii

Capparis cartilaginea

Italian FIRB Research Project:

"Integrated technologies of robotics and virtual environments in archaeology"

ACTIVITY REPORT

PERIOD:25th FEBRAURY - 11th MARCH 2007.

Introduction

This report is about the activities developed by CNR-ITABC and Scuola Superiore S.Anna in Khor Rori, from the 25th of February to the 11th of March 2007.
Such activities have been developed within the context of the Italian FIRB research program, "*Integrated technologies of robotics and virtual environments in archaeology"*.
The project, coordinated by prof. Massimo Bergamasco from Scuola Superiore S. Anna, includes as partners the former institution, the University of Pisa and CNR-ITABC.

This project gives us the occasion to experiment and realize a multi-user virtual reality environment in the web devoted to the scientific community: archaeologists, topographers, historians and also experts in communication of cultural heritage.
The state of the art in this field is still quite pioneer, because there are no Multi-user domains (MuD) for sharing and exchanging cultural and scientific contents, in the field of virtual heritage.
All the data, 3D models, archaeological and historical information, and so on, will converge in a virtual scenario where a web community will interact in real time.
We think it could be an interesting contribute in terms of methodology and learning, for the simulation and the interpretation of cultural archaeological contexts: experts could meet in the virtual space, dialogue, share information, ideas, test simulations and exchange data. They will be able also to modify and update the archaeological virtual reconstruction or the map of the relations of cultural contents, according to their own interpretation and personal hypothesis, discussing them with other users.

This approach favours also the "transparency" of data and methodological approaches, an issue forward which the scientific community feels more and more interested and involved, as many recent international conferences and articles demonstrate.
Making a model transparent means to communicate and to share data source and methodological processes so to encourage and develop the discussion, the educational value and the cultural impact of the project.
In conclusion the multi-user approach and the possibility to edit the 3D environment will enhance the informative exchange, the feedback, the creation and evolution of conceptual maps in the interpretation of meanings and in data sharing, and finally the communication.

CNR-ITABC Activities

Eva Pietroni*, Nicolò Dell'Unto**

*Institute of Technologies Applied to Cultural Heritage, National Research Council of Rome
**Nicolò dell'Unto IMT Lucca

1. Summary

Our work, in the period of the archaeological mission, has been oriented towards both the acquisition and a first phase of digital data elaboration.
These are the main activities:
1. Digital photography on the site through a Nikon D200 in order to obtain photogrammetry and photographic panoramas.

2. Collecting and acquisition of graphic sources and "libraries", preexisting topographical data, images, aereal photos, texts, and general metadata about the site.

3. Digital post-elaboration of acquired photogrammetric and topographical data in order to obtain a virtual reconstruction of the archaeological landscape.

2. 3D reconstruction of the archaeological landscape

In this report we'll discuss in particular the methodology we are following for the 3D reconstruction of the archaeological landscape of Sumhuram (previous item 3).
3D data elaboration involves different kinds of techniques and approaches, according to the level of detail and to the kinds of metaphors we need. All the data and levels of detail will be then integrated and organized in a virtual environment where olistic visions of the territory and "monographic" representations will be put in relation in order to give a complete interpretation of the archaeological landscape.

OLISTIC VISION

2a. 3D reconstruction of the territory from digital level curves
Topographical data previously elaborated have been acquired. They consist in level curves of the Khor Rori territory in AutoCAD. In order to use these data for the creation of a 3D model of the terrain, we had to clean and improve the poly-lines in CAD and to input their correct elevation values (we found them in the archaeological raster map), (fig1).

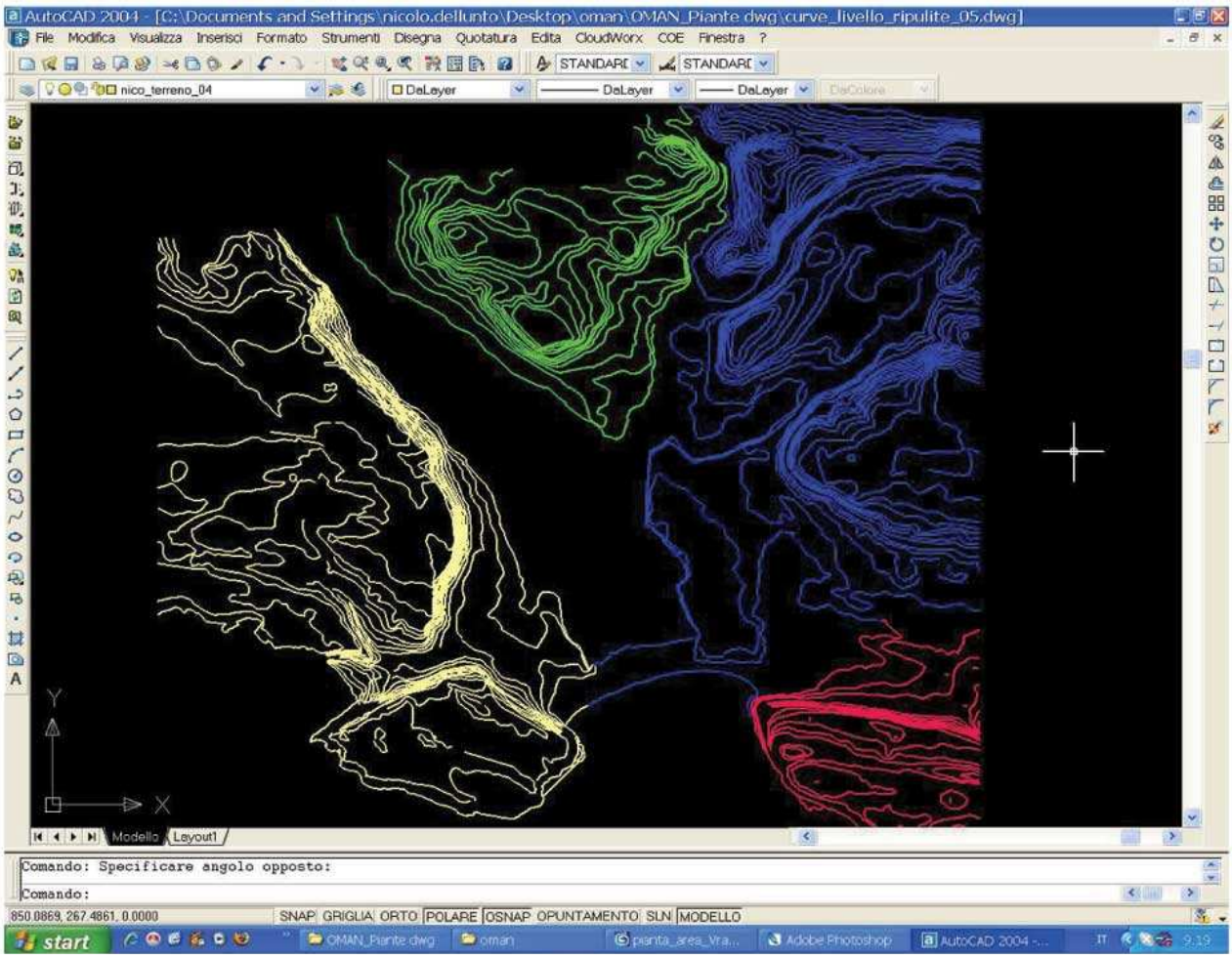


Fig1: level curves in AutoCAD , cleaned and with elevation values attributed

Then level curves have been imported from Cad in 3D Studio Max and the 3D model of the terrain has been generated. Texturing has been realized using aerial photos and patterns optimized for the web (fig.2-3). They will be improved any more in the next days.

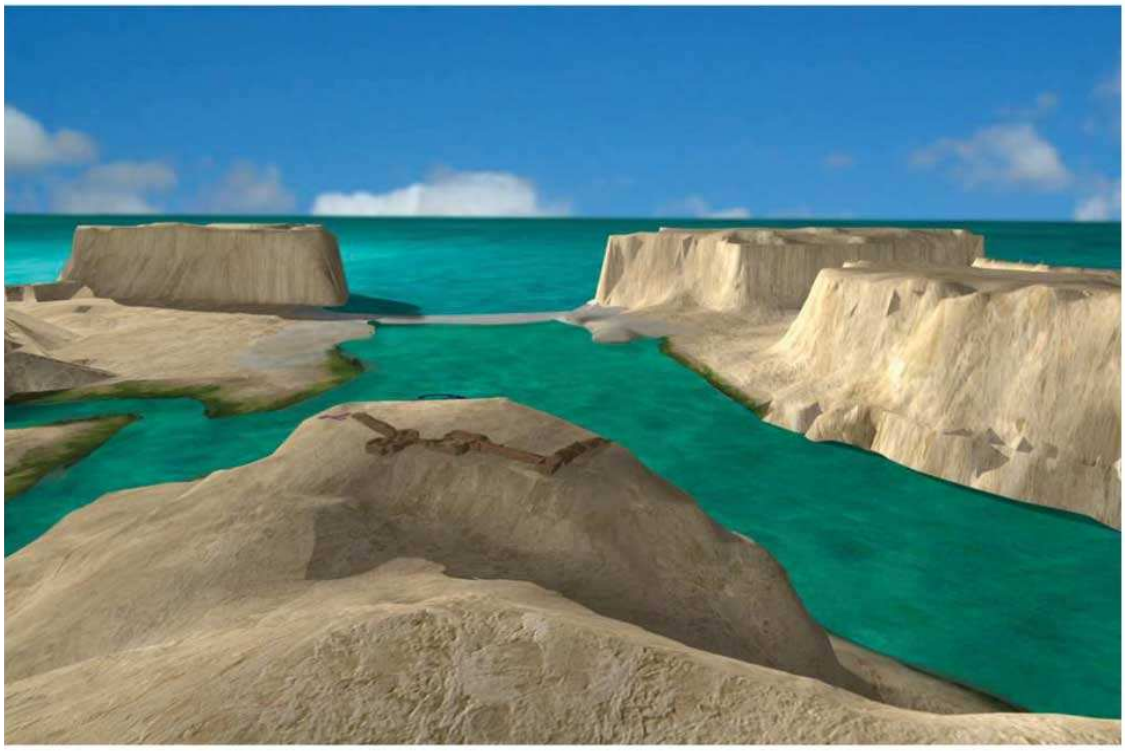
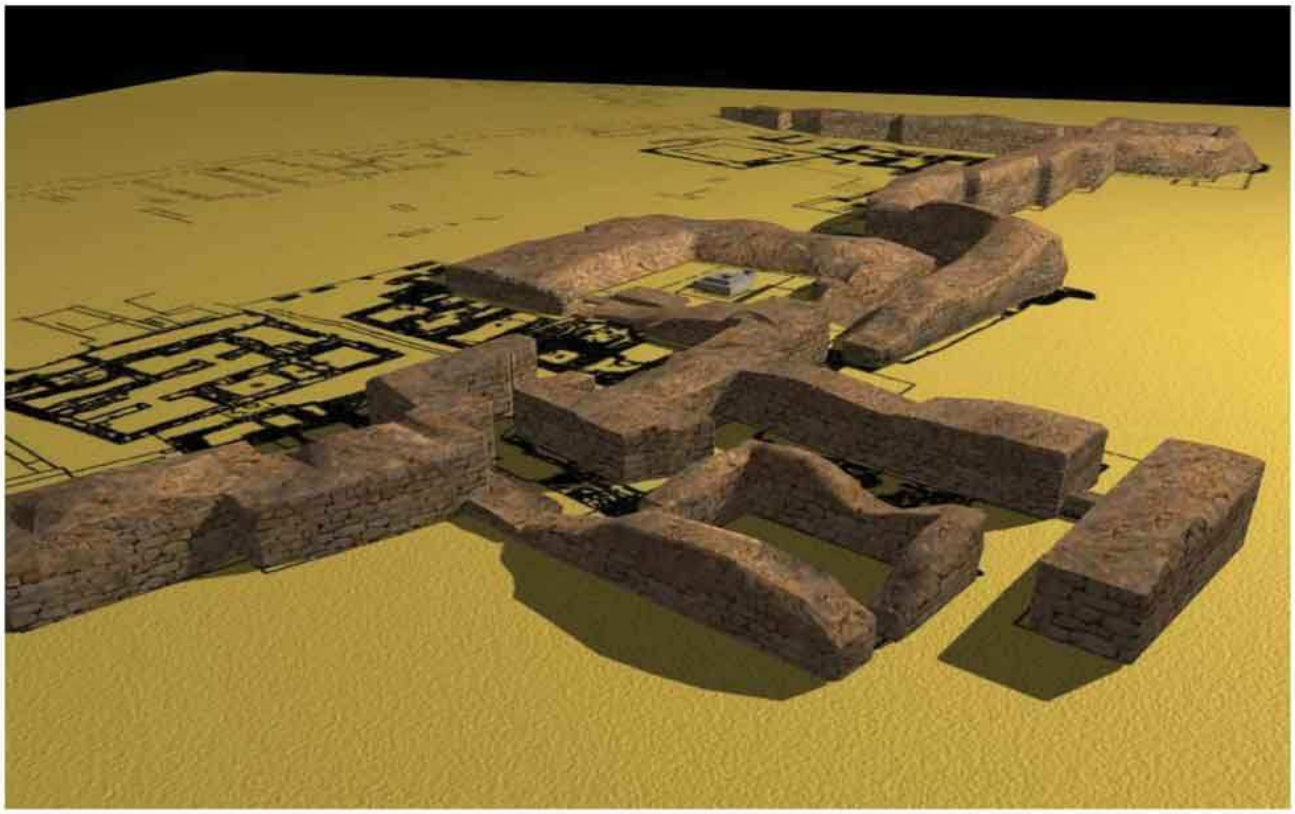


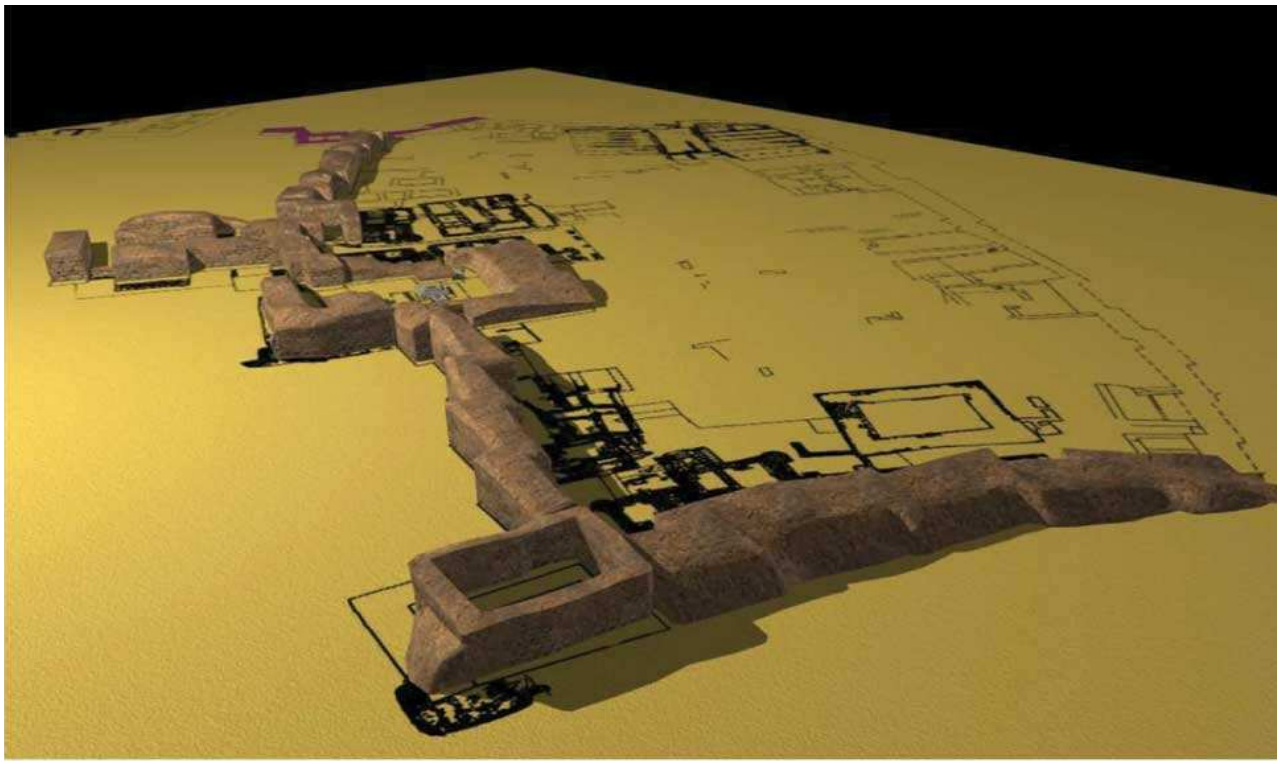
Fig 2 -3: A first elaboration of the 3D model of the archaeological landscape, obtained from curves of level and topographical data.

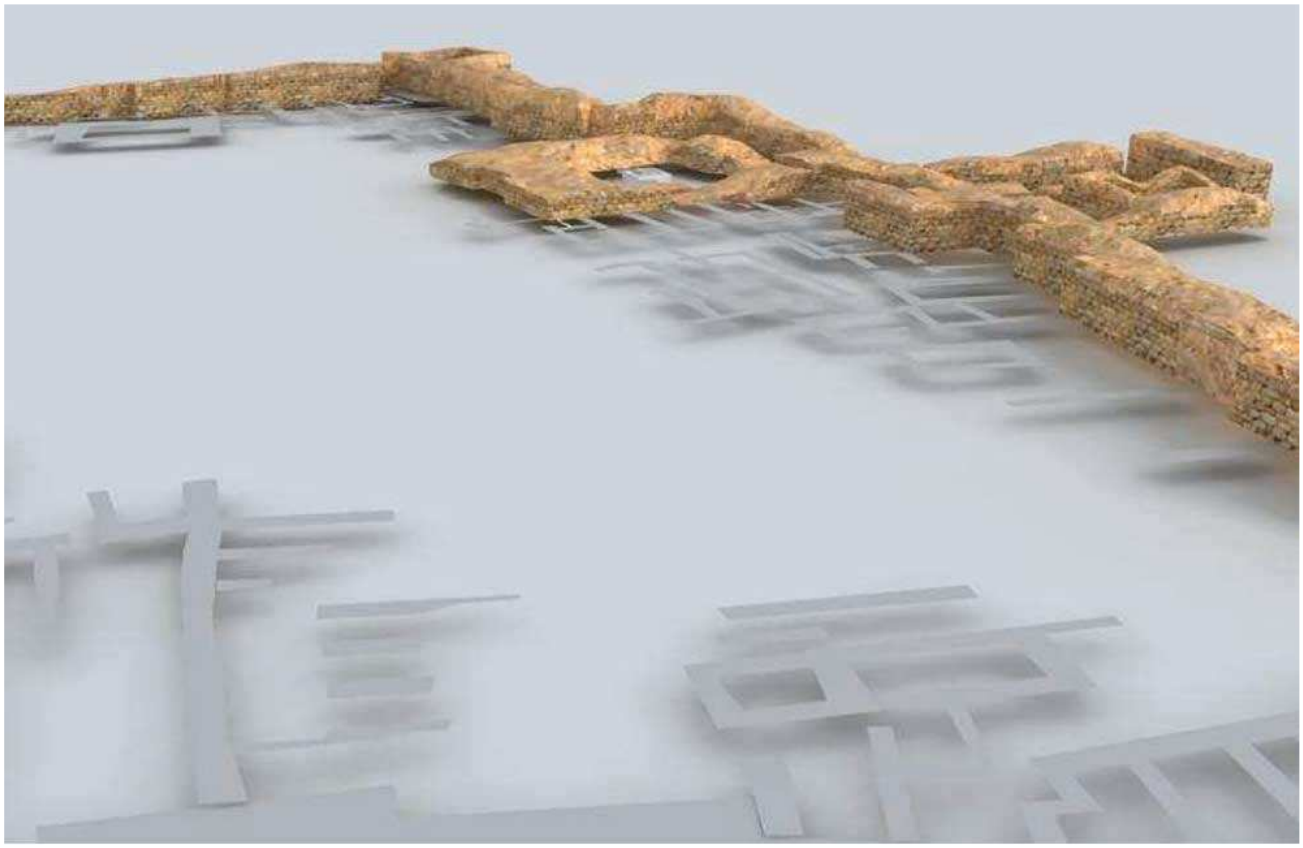
2b. 3D modeling of the general volumes of the site

In order to obtain an olistic vision of the archaeological landscape we need to overlap a simplified model of the excavated site on the hill. In fact the already existing 2D map, in CAD, describes not

only structures and walls, but also traces, irregularities, hidden structures. Because of its complexity it is not easy for users to interpret it and have a good perception of what is really visible and what is hidden.
We are realizing a general 3D representation so to achieve a better perceptive impact in three dimensions. This simplified representation of the site functions just like a 3D map, it cannot have the value of a really metric reconstruction. The model has been just started and will be finished in the next days (fig. 4-5-6-7).







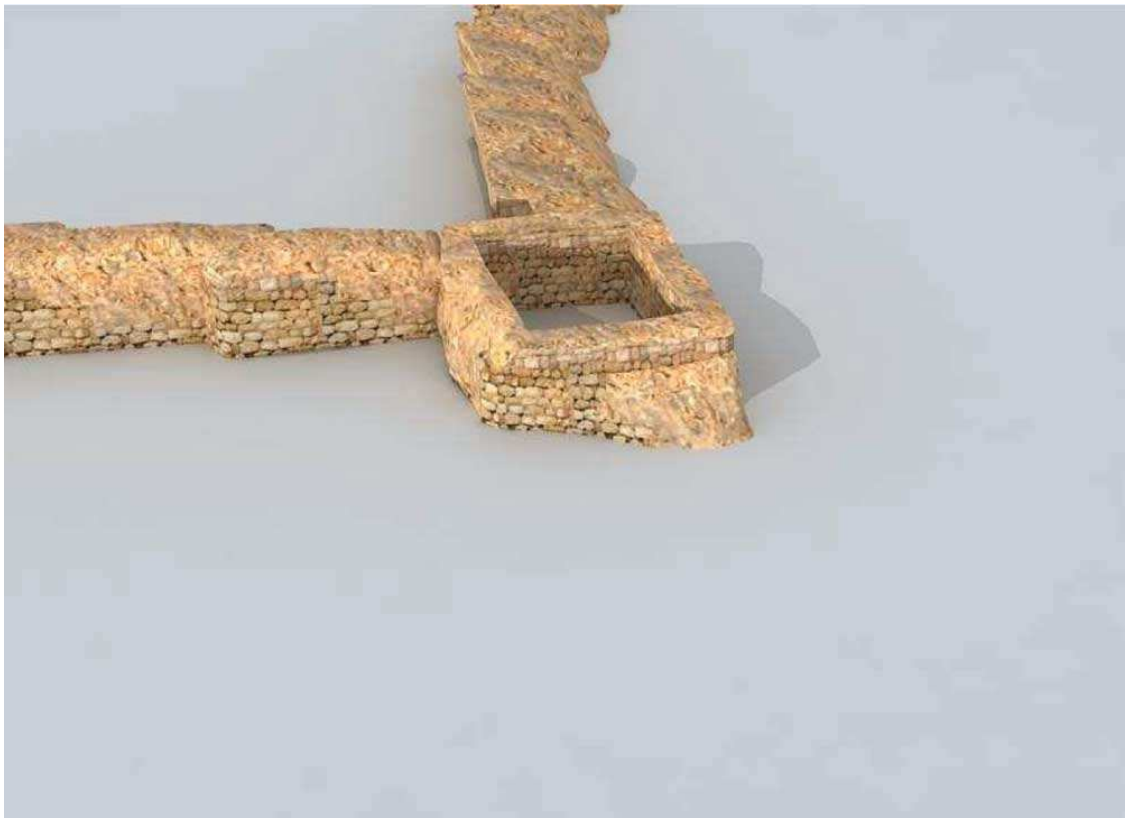


Fig 4-5-6-7: schematic 3D representation of the city, realized on the base of 2D topographical data.

Finally this 3D map of the city has been put on the 3d model of the terrain, as showing by fig. 2 and 3.

2c. digital photographic panoramas

A panorama simulates a virtual environment but the scene is not really modeled in 3D.
Some 2D photographic images, taken at 360_ from a fixed point, are “stitched” and then mapped on a virtual cylinder or sphere (fig 8). User can rotate his point of view from the center of the scene and zoom in and out. Some interactive areas can be set in the panorama in order to access to other panoramas or to any kinds of information.

Fig 8: stitched panoramic image of Khor Rori, developed on a plane. It will be mapped on a virtual cylinder and explored *2* *dimensions.*

MONOGRAPHIC VISION

The area of the market and storehouses that were, in the past, directly linked to the harbour, will be reconstructed more in detail. We think that the presence of the harbour and the commerce of incense are the main cultural key-concept of Sumhuram site and for this reason we have decided to represent this area with more accuracy and to connect much historical information. In every case the architecture of the software we are going to develop will be open so, in the future, it will be possible to update the model representing also other areas with the same level of detail.

2d. photomodeling (photogrammetry)
This technique allows us to calculate measurements and constructs 3D models through digital pictures using the same outset of photogrammetry. The control points taken directly on the images are projected in a virtual space by the calculation of the optical lines coming from every picture. The models created by these techniques are scaled and textured and it is possible to export it in every format. They are optimized for real time applications.

2e. computer vision (photogrammetry)
Computer vision has been developed by Louven University (Epoch project) and allows us to construct 3D models from a set of digital photos taken all around the object.
Photos are sent to a server where specific software, based on a pixel-recognition algorithm, orientates the photos in the 3D space.
This is possible because software defines automatically some control points through which photos are oriented.
So the server sends again oriented photos to client.
A client-player generates the 3D model, based on couple of oriented images. Models obtained from each couple† have the same spatial coordinates† and they will be automatically aligned in a 3D modeling software.

2f. The reconstructed landscape
The olistic vision (landscape and simplified volumes of the whole site) will allow us to access to other kinds of information and visualizations.
First of all the reconstructed landscape, that is the possibility to switch from the present to the past and observe how the landscape has been changed through the time.
In the reconstructed landscape we'll try to simulate the vegetation covering the terrain, and for this reason we are collecting images and photos of plants taken all around the territory. Together with the botanists of the University of Florence, working here and coordinated by Prof. Mauro Raffaelli, we have crossed some desert areas of Oman in order to find and document incense and other plants that will be introduced in the virtual reconstruction of the ancient archaeological landscape of Sumhuram.
We'll simulate also the harbour functioning and its activities for the commerce all over the incense routes.

Also the market and storehouses, in the city, will be reconstructed as they could be in the past. In order to make this with a good level of reliability, we have begun to collect sketches, drawings and discuss them with Prof. Avanzini and other experts.
The final software will allow us to edit the space and the model changing elements in order to simulate different solutions and better interpret the structures and the space.

2g. Contextualization of the objects
Objects coming by the market area, acquired by Scuola S. Anna through scanner laser, will be integrated and contextualized in the virtual environment and many historical information will be connected to them (comparative images, texts, audio comments, and so on).

2h. Access to deeper levels of detail
Selecting particular areas of the site, in the olistic view, we'll access to other visualizations and levels of detail: panoramas taken in about 15 different positions on the site and monographic representation of the market and warehouses, realized through photogrammetric techniques, as described before.

Metadata and any kinds of information will be connected to 3D models, so to make the 3D

environment an interface to organize, integrate, simulate, access and query cultural contents.

The post-processing of all the acquired data has been started in Khor Rori and will be finished in Rome during the next weeks.

3. Conclusions

We think that this project could be a good occasion to experiment new digital metaphors for the interpretation of cultural contexts, for the editing of conceptual maps and for data sharing in the web.
Another important result will be the strong impact in the field of learning of methodological techniques for 3D acquisition and representation of virtual heritage. Users, in fact, will have the possibility to show and discuss the differences among data acquisition techniques (photogrammetry, photomodelling, computer vision, scanner laser, computer graphic, and so on) comparing the efficacy of maps and 3D representations in relation with the level of detail required case by case and the kind of cultural contents we want to extract and communicate. According to us the integration of different techniques is the best solution to achieve a global visualization and interpretation of the archaeological landscape.

Percro, Scuola Superiore S.Anna Activities

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1. Introduction

The focus of our work during the reported period has been on three dimensional acquisition and reconstruction of small findings from Sumhuram.
The goal of this task is to provide digital copies for a set of objects which will be integrated in the virtual environments developed in the context of the project.
The equipment employed in the acquisition phase is a Laser Scanner, the Minolta VI 910 Non Contact Digitizer, which allows high quality capture of 3D point clouds, delivered with coupled spatial and color information.
A single scan of an object is relative to a particular view of the same, in analogy of what happens in traditional photography. The consequence of this intrinsic limitation is the need to acquire and merge multiple scans (taken from different views) of the same object, in order to obtain the final 3D digital reproduction of it. For this reason the acquisition phase has to be followed by a data processing phase, which includes point clouds registration and merging, noise reduction, surface generation and recovery of unwanted features (such as small gaps which may appear in the surface due to object's self-shadowing).
We acquired 11 objects selected from the small findings from Sumhuram and completed most of the related data processing phase.

2. 3D Data Acquisition

The select objects are all exposed at Al Bahalid museum in Salalah. In order to perform the laser scan of each one, the museum staff temporarily removed them from showcases, letting us work on each peace in an office environment.
The scanner we used is controlled by a laptop. The software used is "Polygon Editing Tool Ver.2.02", which comes as standard Laser Scanner control software from Minolta.

The following objects have been acquired:

S133 - Limestone incense burner

S643 - Limestone tall incense burner

S10 - Limestone incense burner from *extra-muros* temple

S452 - Squared limestone incense burner with handle

S484 - Round limestone incense burner

MB97 - Bronze tripod incense burner

MB99 - Bronze spout in form of horse protome

MB96 - Bronze inscribed bowl

S12 - Limestone altar from *extra-muros* temple

- Fragment of green glazed ware from Gulf area.

- Amphora fragment

- Bronze coin

3. 3D Data Processing

In order to illustrate the process which allow us to reconstruct the digital copy of an object we show some screenshots of the main elaboration phases, considering a single object among those which have been acquired.
The software adopted for this work is mainly “Geomagic Studio (ver 4.1)” from Raindrop and custom made software we developed for color correction.

3.1 Point cloud registration (alignment)

Using the aforementioned software the user aligns the different scans. First the user has to specify at least three couples of matching points on the scan pair considered, then the software automatically minimizes the distances between the two, delivering an aligned composition of the scans. The process has to be repeated incrementally for all the different scans, until all of them are correctly registered.

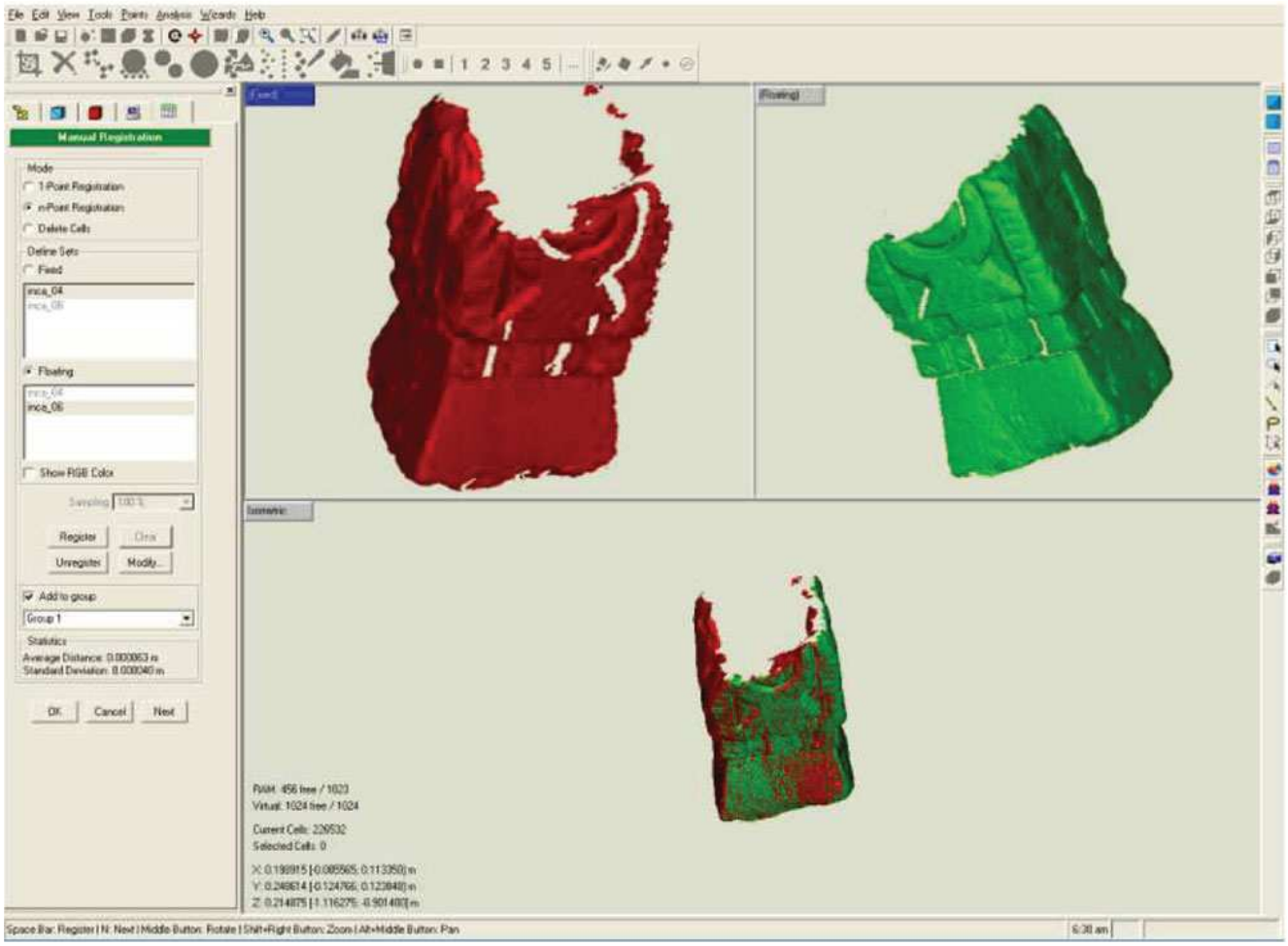

Fig. 2 Point Clouds registration: Unaligned point clouds (top) and result of the registration of the two (bottom).

Once the registration is completed the more elaboration is applied. A complete surface is generated and cleaned by removing unwanted components and noise. Moreover small gaps which may appear on if are filled (see Fig. 4).

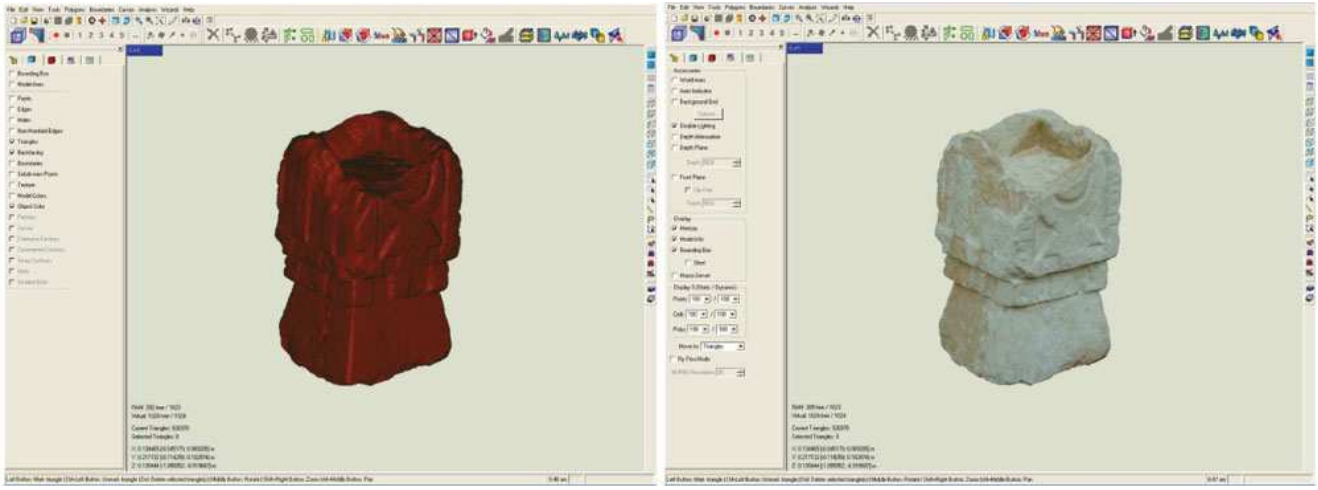

Fig. 3 The final 3D shape acquire: just the surface (left) and the surface with colour (right).

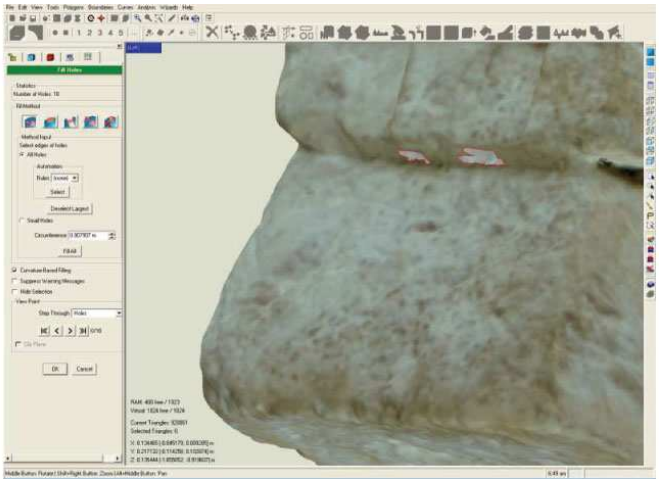

Fig. 4 Small gaps filling phase.

4. Conclusion and Future Work

The laser scanning campaign has been completed, as most of the work concerning the processing of the resulting data. We will complete the latter phase in the immediate future in order to deliver accurate and highly detailed digital models. Such models are important as faithful digital copies of the originals.

Nevertheless their complex geometry (up to millions of polygons for a single object) makes the related visualization and manipulation tasks too demanding (time consuming) to be suitable for an interactive virtual environment.

We already faced this problem in analogous settings, developing Computer Graphics techniques which combining geometric simplification and detail texture application allowed us to include in a virtual environment “lighter” version of the original models with visual appearance undistinguishable from the original, high quality, 3D model. Such techniques will be applied on all of the models produced.