
The choir of Romitorio de San Michele with painted walls and altar

NIKU-project

Nemi as a laboratory for developing methods for cultural environments definition and cultural heritage monitoring

Case study of Romitorio de San Michele
22-26 July 2001

Field report

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Preface

This is a *field report* summing up work done at Romitorio de San Michele in Nemi, Italy, July 2001. The report also gives proposals for further work. In appendix 2 forms for GIS-based monitoring of the rock-cut chapel can be found. The report does not aim at a comprehensive understanding of the chapel and its history, and, awaiting results of on-going art historical investigations, many interpretations related to building and restoration history might be highly speculative. Field work was undertaken together with Jørgen Solstad. Also thanks to the other members of the Nemi project: Birgitte Skar, Wenche Eriksen, Anne-Cathrine Flyen, Lars Erikstad and Vegard Bakkestuen.

Trondheim, 5. August 2001
Per Storemyr

1 Introduction

This report deals with the construction, materials and weathering of the abandoned, small rock-cut chapel "Romitorio de San Michele", situated just below the town of Nemi and above the Nemi crater lake in the Alban Hills near Rome. The chapel was chosen as a case study in the NIKU[1]-project " Nemi as a laboratory for developing methods for cultural environments definition and cultural heritage monitoring".[2]

The entrance to Romitorio de San Michele (after clearing the facade of "greenery")

The objective of the case study was to survey the chapel in terms of construction types and materials used, as well as damages and weathering forms. Furthermore, this survey should lead to an evaluation of the most important threats to the chapel and its decoration (risk analysis) as well as to a proposal for monitoring the evolution of damages and weathering forms. Another important aim was, on the background of the case study, to propose ways of representing the findings in databases/GIS-systems. Developing a GIS environmental/cultural heritage monitoring system is the ultimate aim of the whole project.

Field work was undertaken during 4-5 days in July 2001. Simultaneously, other project collaborators statistically established areas for digital photographic monitoring of the frescos in the chapel and surveyed other sites around Lago de Nemi (mainly the large Roman Villa, which is currently under archaeological excavation[3])

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[1] Abbreviation for: "Norwegian Institute of Cultural Heritage Research" (www.ninaniku.no)

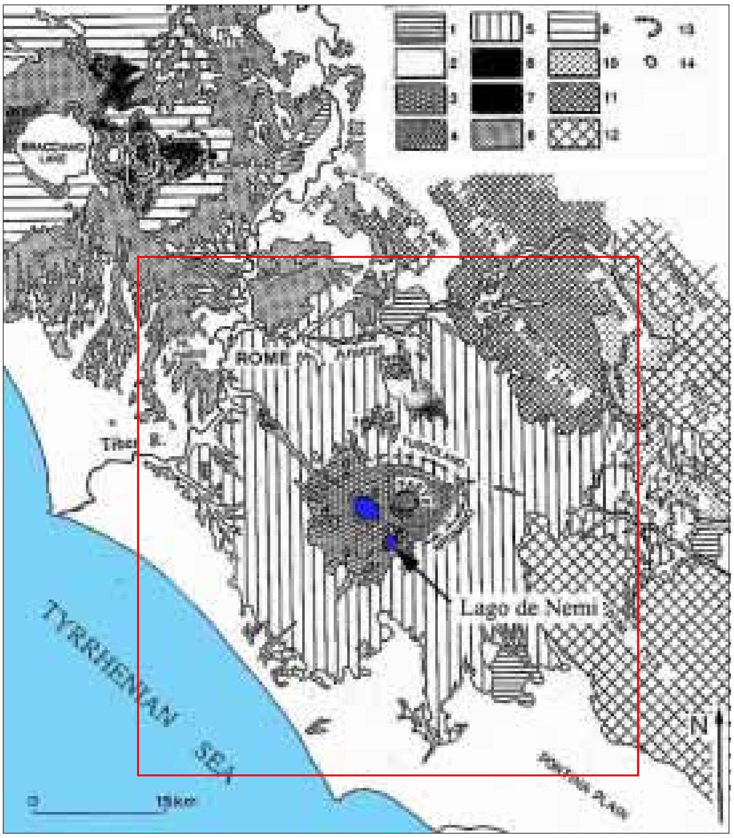
[2] See project description: "*Prosjektbeskrivelse: Nemi som laboratorium. NIKU som en europeisk aktør - metodeutvikling på kulturmiljøavgrensing og miljøovervåking*, NIKU 2001. A short version of the project description is also available in English. The aim is to continue the project over the next 3 years.

[3] See: http://www.dkinst-rom.dk/nemi/villa/index.htm

Due to the short field work period, and the fact that virtually nothing is known about the building and restoration history of the chapel, the survey had to be limited to selected parts of it. Thus, in addition to the chapel's near surroundings, a relatively detailed survey was made of the whole east wall of the interior, as well as of parts of the frescos.

2 Location of the chapel

The chapel is located in dense forest on the north-east side of the Nemi crater, some few tens of metres (elevation) below Nemi town. The Nemi crater lake (at 316 m above sea level) was developed during the last stages of the evolution of the so-called Colli Albani volcano (or Latian volcano) some 23.000 years ago.[4] Although there is no volcanic activity at the moment, the Colli Albani volcano is not completely "dead". However, its eruptive phases seem to occur with very long intervals. Earthquake activity occurs, as exemplified by the 1995 Rome quakes.[5]



Location of Nemi and geological map of the Colli Albani volcano outside Rome. Geological units associated with the volcano are: 1) Travertine, 2) Plio-Pleistocene sedimentary units, 3) Colli Albani: final hydromagmatic phase products (until c. 20.000 BC), 4) Colli Albani: Faete phase products (300-200.000 BC), 5) Colli Albani: products of the Tuscolano-Artemisio phase (ignimbrites etc.; 600-360.000 BC), 6) Lava flows, 13) Caldera rims, 14) Crater rims. Map and unit description after http://www.geo.mtu.edu/~boris/gifs/Albanimap.JPG

The steep, some 150 m high (from lake to crater edge), and very fertile crater has been intensively used by humans and it had a central position as a recreational landscape for the Romans (villas, the famous Nemi ships, the Diana temple, associated cistern systems etc.). The towns of Nemi and Genzano on the edge of the crater were established in the Middle Ages. Cultivation is presently taking place along the lake shore, but the terraced hillsides are in very little, if any, use. Animal grazing is neither taking place at the moment, which means that the hillsides are heavily overgrown. The crater is protected because of its biodiversity.

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[4] See: Caputo, C., Funiciello, R., Battista la Monica, G., Lupia Palmieri, E. & Parotto, M. (1974): Geomorphological features of the Latian Volcano (Alban Hills, Italy), *Geol. Rom.*, 13, pp. 157-201, and: de Rita, D. & Funicello, R. (1982): Guidebook for the field excursions to Alban Hills. *Workshop on explosive volcanism*, Consiglio Nationale delle Ricerche (Italy) & National Science Foundation (USA), May 1982.

[5] Up to 3,9 on the Richter scale, see http://www.geo.mtu.edu

Lago de Nemi as seen from Nemi town towards Genzano in the south-west

Romitorio de San Michele is located in dense forest below Nemi town, on the north-east side of the crater. Arrows indicate its position

This painting from 1870 shows the rather barren Nemi hillsides, as compared to the presently densely forested crater. Note the structure indicated by an arrow. This appears to be a "house" with two openings, which seems to be located at the same spot as the chapel. Is the structure representing the chapel? (Photo of copy of painting from Museo de Nave Romani by Nemi)

3 General description of the chapel

The chapel is cut into one of the many basalt cliffs creating a series of terraces below Nemi town. More accurately, it is situated within an almost unconsolidated, very workable, thin pyroclastic ("crystal" tuff?) sequence overlaid by fractured basalt "blocks".

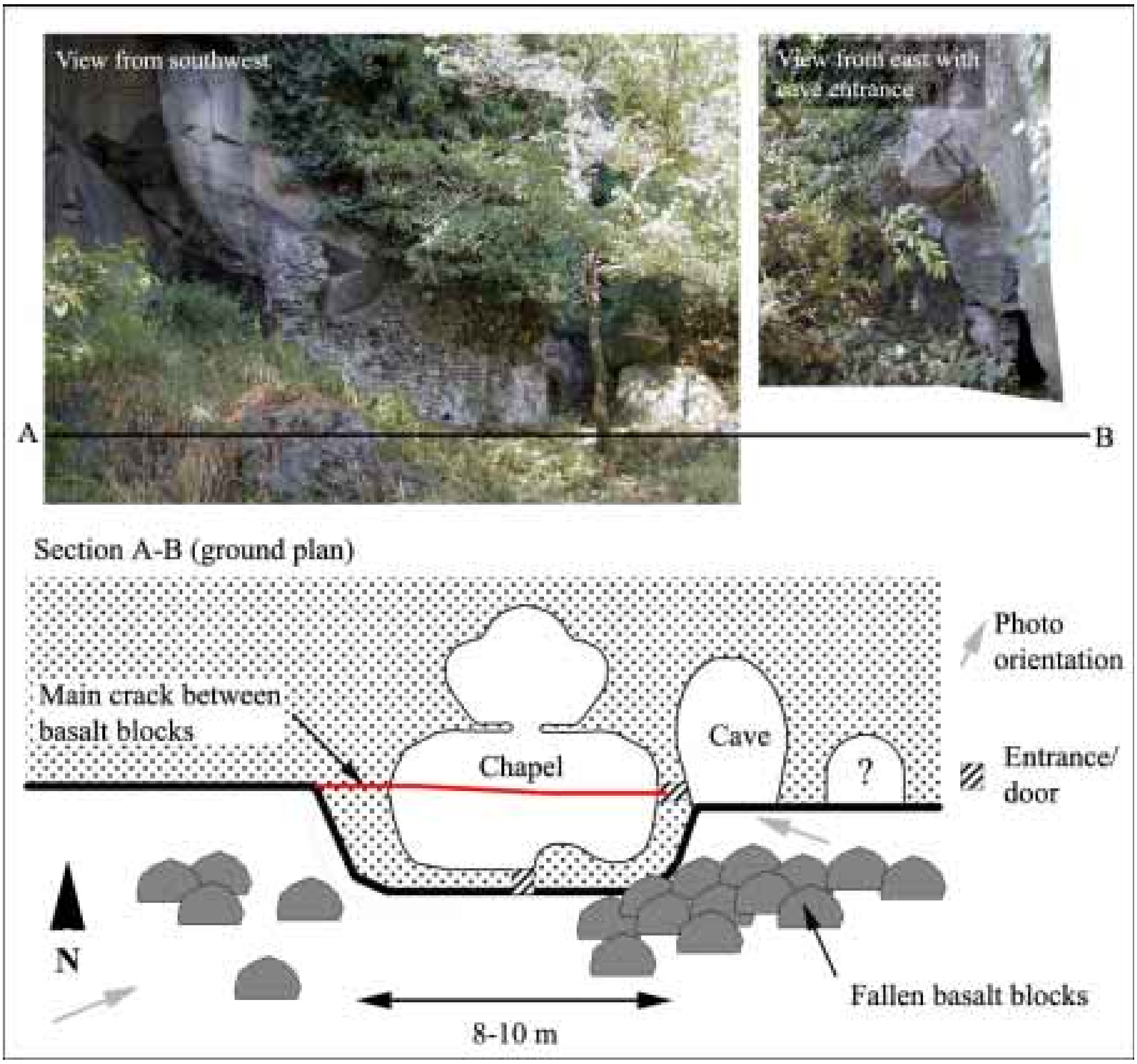
Although having a rather irregular outline, it is possible to divide the chapel in a larger nave and a smaller choir, which are separated by low masonry walls. The main axis of the chapel is about N-S, with the entrance, or portal, on the south side. The length (N-S) is about 8,8 m, whereas the nave is some 7,6 m broad (E-W) and the height generally 2-3 m (and perhaps a bit more at places in the nave). Being rather roughly cut into the tuff, there is usually a fluid transition between walls and ceiling.

The choir has three apse-like structures and several smaller niches, as well as a large altar, probably (at least) partly made from reused Roman elements. 15th century frescos can be found on two of the apses, displaying the Crucifixion (W, dated to 1471 according to an inscription) and the Holy Family (E). There are also smaller frescos attached to the two main ones.

In the nave a fresco (a Row of Saints) can be found on the south-east masonry wall close to the entrance. This semi-circular masonry wall was probably made to strengthen the tuff within it, and preventing a large basalt block making up part of the ceiling to fall. A masonry bench also runs along

Left:
The east side of the nave

Below:
***Very** rough sketch of the ground plan of the chapel and its near environment*



this wall. Another main feature of the east side of the nave is a now blocked door leading to a man-made cave just beside the chapel (see below). On the other side of the entrance there is no such masonry wall, and although there are some niches and several unexplained "holes" in the walls, the west side of the nave is generally simpler than the east one.

In addition to the frescos (and the altar), the only additional decoration of the chapel is two or three small stucco angels, one of them situated above the entrance.

The exterior of the chapel is made up of rough masonry below the 5-7 m high basalt wall on the west side. A recession in the masonry wall close to the entrance suggests that there might have been a now removed structure at this place. Several fallen, large basalt blocks, as well as dense vegetation makes it difficult to see the exterior of the east part.

4 The cave(s) on the east side of the chapel

The cave(s) on the east side of the chapel are also difficult to observe at first glance because of vegetation and fallen basalt blocks. However, it would seem that the door from the chapel enters the outer side of the westernmost cave, indicating the close connection between the two structures. This cave is definitely man-made (tool marks can be seen in the tuff) and some 4-6 m deep. Its floor lays on almost exactly the same level as that of the chapel. Horizontal "lines" of salt efflorescences indicates that the cave is (or was) occasionally filled with water. This is reasonable to suggest because the fallen basalt blocks outside may prevent rain water to escape.

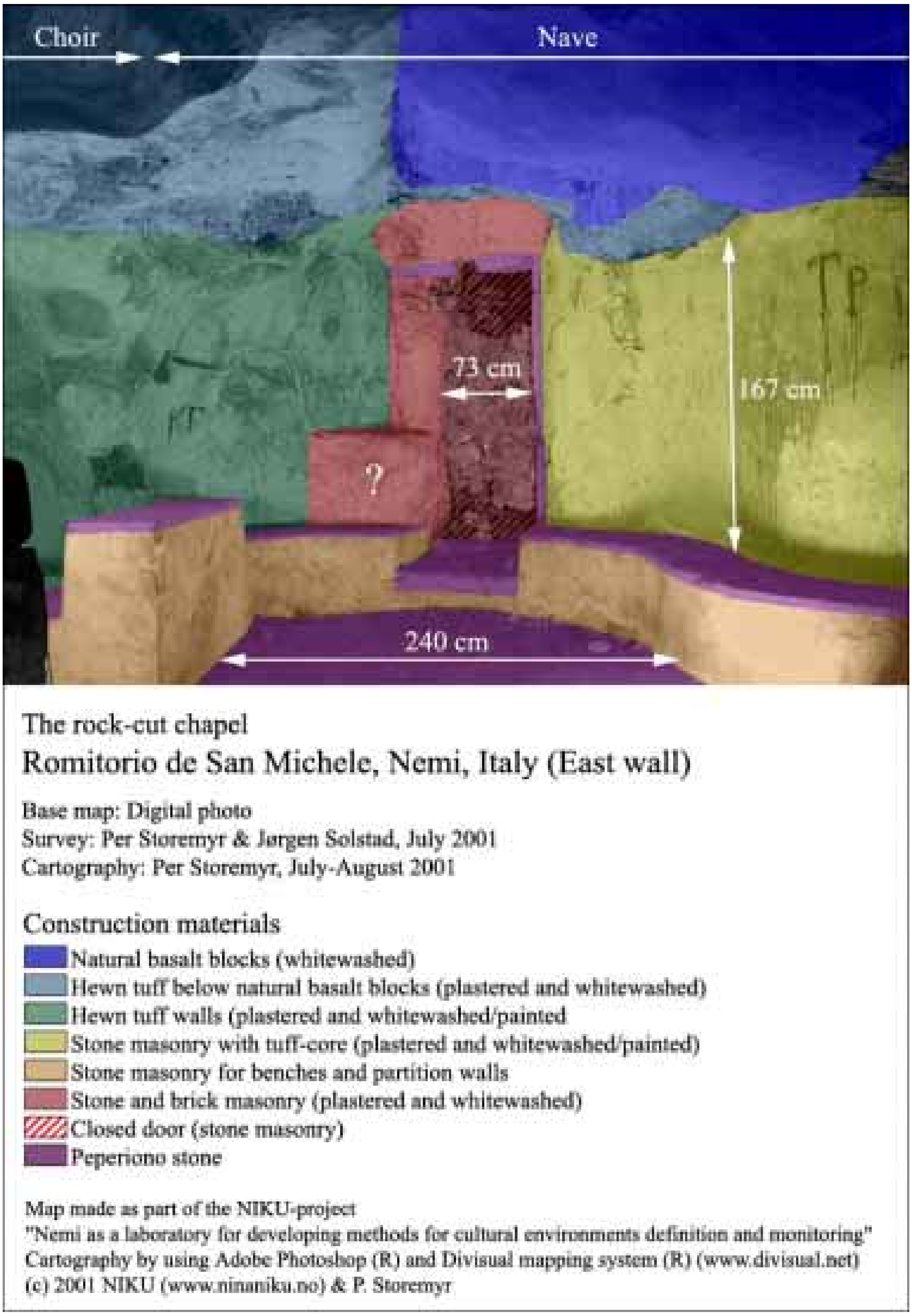
Another possible cave is situated just to the east of the open one. The entrance to this cave (if it is not only a small hole in the tuff) is almost completely covered by fallen basalt blocks.

We don't know what the cave(s) represent or what they were used for. The connection to the chapel indicates however that they might represent a retreat for monks or other persons being attached to the chapel.

The westernmost cave. Left: West side close to entrance with masonry structure. Arrow indicates the location of the former door to the chapel. Right: Interior of the westernmost cave. Red colour is probably algae.

5 Survey of construction materials

The east wall of the chapel was selected for a more detailed survey of construction materials. As shown on the simple map below, the ceiling consists of whitewashed natural basalt blocks. At places the tuff has not been completely removed from the basalt making up the ceiling, but heavily weathered spots indicate that the tuff layer is rather thin here.



Map of construction materials on the east wall of the chapel

The whole choir and most parts of the nave have plastered tuff walls, but in the south-eastern part of the nave the tuff is strengthened by apparently rather irregular, plastered stone masonry, giving the wall a semi-circular appearance. Plastered stone masonry can also be found around the entrance to the chapel, which has a semi-circular arch and is permanently closed by a gate made from iron bars, as well as around the blocked door to the cave. The masonry used to block the door is very irregular and unplastered.

Peperino stone on the floor of the chapel with its characteristic speckled appearance (width of field c. 10 cm)

Benches in the nave are made of plastered stone masonry and covered by slabs of Peperino stone, a pyroclastic stone extracted from several quarries around Rome and widely used from the Roman times until today. Finely worked slabs of Peperino stone are also found on the floor, on the stone masonry separating choir and nave, as well as around the door leading to the cave and on small benches below the east and west apses of the choir).

The altar (se picture on the cover) is probably partly made from reused (and sometimes reworked) Roman marble elements. The provenance of the marble has not been determined, but it seems that at least some of it comes from Carrara.

The large slab used as table is a speckled (hornblende and/or mica?) granite variety, probably a granodiorite. It may be a reused Roman element, originating for instance from quarries in Egypt's Eastern Desert, or a stone extracted much later at for instance Sardinia or elsewhere.

6 Frescos and overpaintings

The three late 15th century frescos appears to be the oldest visible paintings in the chapel. Very preliminary stereo microscopy indicates that the paintings really are executed in the fresco technique, since the paint is tightly fixed to the intonaco and not forming a clear separate layer (samples 11 and 13, see appendix 1). Moreover, the upper part of the intonaco, including the pigments, have a crustiform appearance, which is also indicating that the paintings were executed on wet mortar.

Our investigations of the frescos were very superficial and we were for instance not able to distinguish between different day's work. However, it would seem that there is a difference between the two frescos in the choir and the one in the nave. The latter painting is more "vigorous" - a feature that especially can be observed on the faces of the figures. Moreover, visual observation shows that the paint is a bit "layer-like" on the nave fresco. Thus, these features may indicate that the paintings have been executed by different painters.

The Holy Family - fresco on the east side of the choir

A Row of Saints - fresco in the nave

However, it should be considered that the nave painting is executed on plastered masonry and situated close to the entrance, whereas the choir paintings can be found on plastered tuff in the inner part of the chapel where the conditions are much moister. This might have been the situation also when (and after) the paintings were executed, meaning that the choir paintings would form a "better" upper crust of calcite, which would fix the pigments stronger to the substrate. Another feature is, probably due to the moister conditions, that the choir paintings are more strongly marked by colour changes than the nave paintings, meaning that it is harder to interpret original features on the former.

The presence of fragments of whitewash on the frescos shows that they were once overpainted and later brought to light again.

It also seems that on the whitewash covering the frescos various secondary paintings have been executed. They mostly have the form of lines and perhaps geometrical patterns and usually come in yellow and reddish colours.

Over these paintings another layer of whitewash can be observed, showing that whitewashing parts of the chapel was undertaken at least twice after the late 15th century.

Moreover, it seems evident that the overpainting on the frescos were stripped off after the last whitewashing campaign.

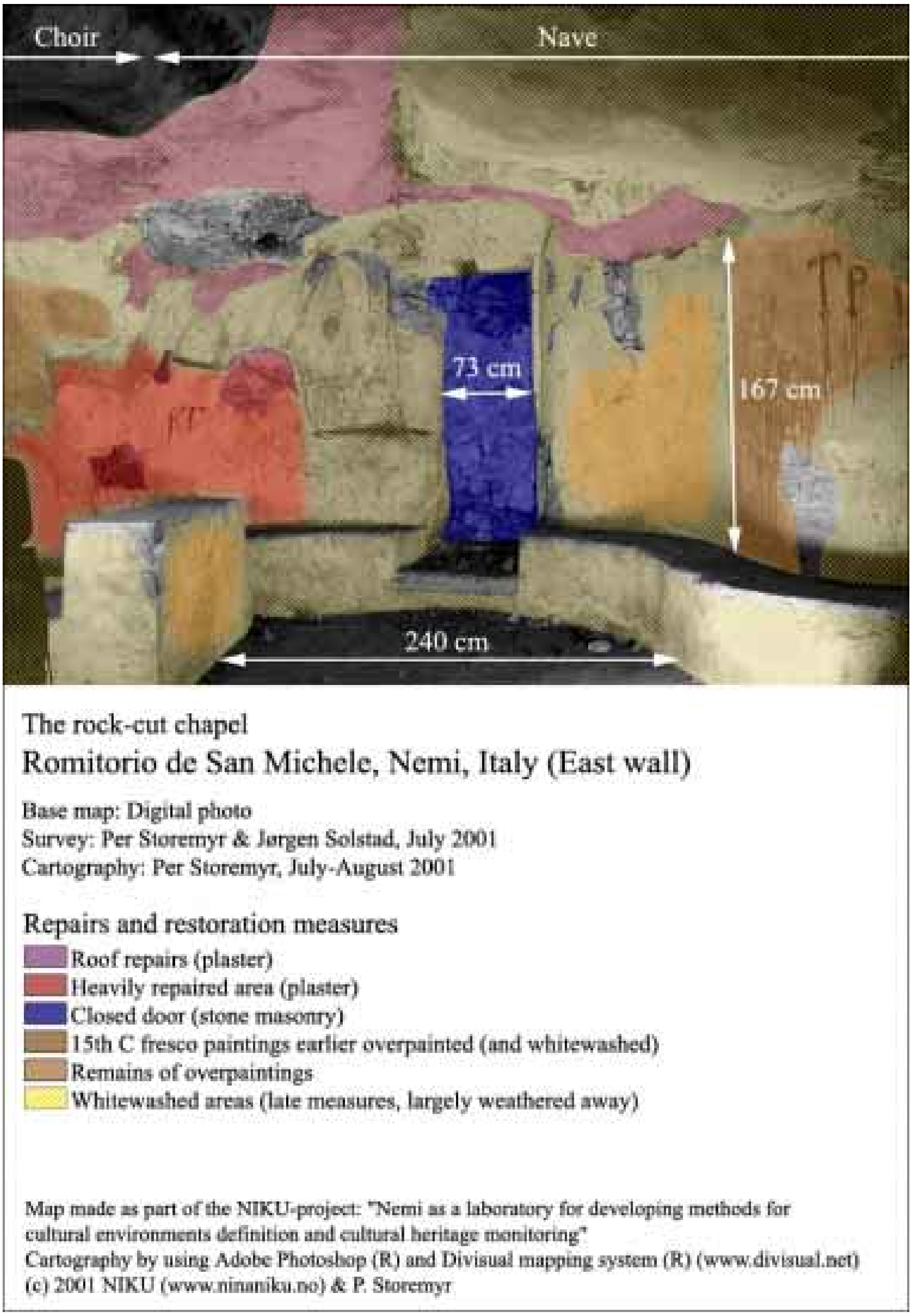
Above:
Comparison between a head in the Crucifixion and the Row of Saints.

Middle:
The yellowish line above the Crucifixion is painted (in fresco?) on whitewash having covered also the fresco.

B elow:
Detail from the north side of the Crucifixion showing that the yellowish secondary paint has been covered by a layer of whitewash

7 Building history and restoration measures

The overpainting measures mentioned in the previous chapter are important when trying to understand the hitherto unknown restoration history of the chapel. In addition to the two known whitewashing campaigns after the 15th century, there are many evidences of plaster repairs, as shown on the map below.



Sketch map of repairs and restoration measures on the east wall

Large plaster repairs are particularly evident on the part of the ceiling made on tuff, as well as on the east wall of the choir and adjacent areas in the nave. Interestingly, these repairs have been executed on surfaces quite close to the cave. Is there a connection with regard to weathering between these features?

The closing of the door in the east wall of the nave must have been a very late measure, probably undertaken well after the chapel was abandoned. This is because the rough masonry has not been plastered and whitewashed. Perhaps the closing must be regarded as a security measure, preventing basalt blocks and masses of earth to fall into the chapel. On the outside towards the cave, the door is almost completely covered by such fallen debris. It might be proposed that this measure, as well as stripping off the whitewash covering the frescos and some of the plaster repairs are restoration measures of the 19th or 20th century.

In order to learn more about the restoration history of the chapel, local people should be considered a very important information source; one simply has to ask around. Moreover, various repair mortars could be analysed with regard to possible cement content. Also the altar painting with its strong blue colours should be analysed with regard to the blue pigment. In addition, one should look for more inscriptions. And what does the year 1963 means? This year has been inscribed at several places, especially on the altar.

The painting of the frescos in the late 15th century shows that the use of the chapel was at a heyday at this time. But does this mean that it is a Renaissance chapel? I consulted building archaeologist Øystein Ekroll and architect Arne Gunnarsjaa[6] on this matter. After having seen pictures of the chapel, both of them got the feeling that it is much older, rather dating to the early Christian era, especially because of the rough outline. And why is the name of the chapel St. Michele? The St. Michael's cult was largely abandoned and replaced by St. George in the late Middle Ages. Only further studies can clarify the building history of the chapel.

8 Climatic conditions

Before describing the damages and weathering phenomena in and around the chapel, a short note on the climatic conditions will be given.

Nemi has a Mediterranean climate with warm, relatively dry summers and mild, wet winters. At the Velletri station (south-east of Nemi, 352 m a.s.l.),[7] the annual average temperature is 15,1ºC, with January as the coldest (7,1ºC) and August as the warmest (24,6ºC) month. The temperature rarely reaches the freezing point and the absolute maximum has been recorded to 40ºC. Average relative humidity ranges from 60-70% in August to 80-90% in February. Rainfall is frequent in the cold seasons and heavy, short thunderstorms are not uncommon in the summer. The annual precipitation is 12-1300 mm and there is on average one day a year with a bit of snow. The main wind direction is south-westerly.

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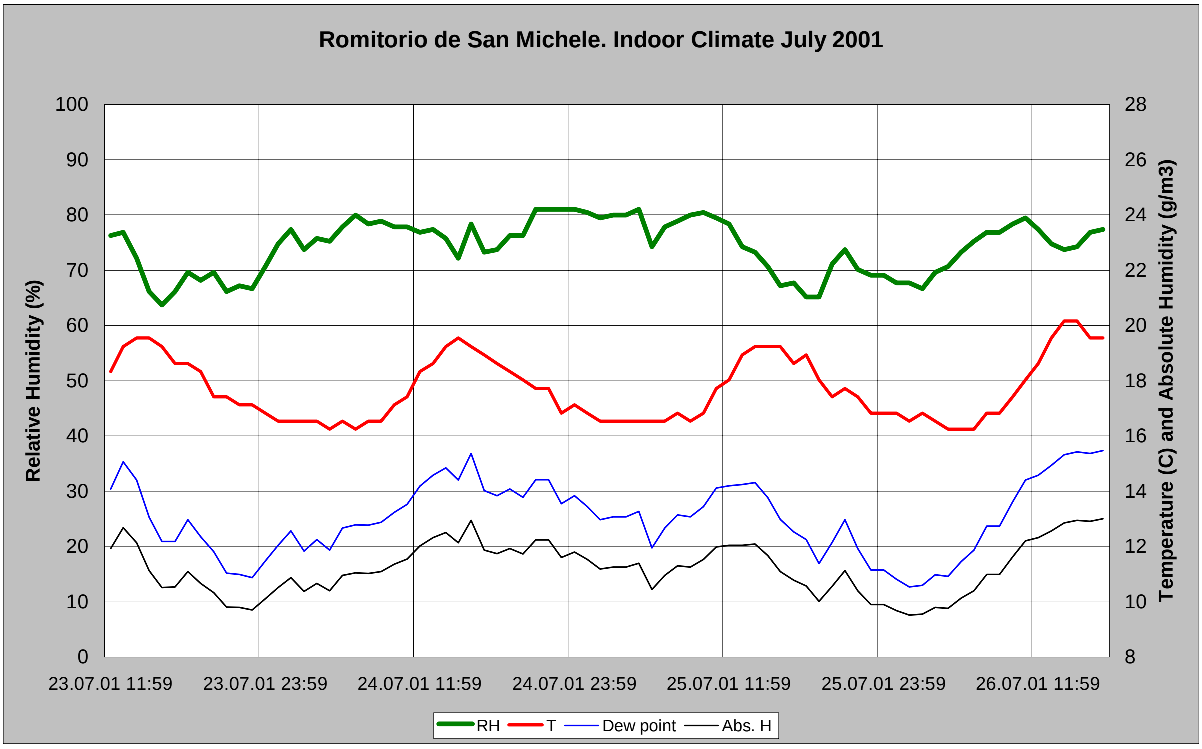
[6] Both scientist with The Restoration Workshop of Nidaros Cathedral

[7] All climate data from the Velletri station, 1921-1966 period, see Caputo et. al. (1974) (op.cit.)



Temperature and relative humidity in the chapel (hourly values). Tinytag Ultra datalogger. Measured 10-15 cm below the ceiling in front of the Altar

Although the chapel is open to the surroundings through the entrance and some smaller holes in the walls, it of course has a general climate very much influenced by the annual average temperature and humidity. Its climate is moderated by the rock masses in which it is situated.

In the fieldwork period, during which the weather was hot and sunny (max. c. 30ºC), we recorded temperature and relative humidity in the chapel on an hourly basis. The difference between night and day (T: 16-20ºC, RH: 80-65%) is probably even more marked in spring and autumn when nights are generally colder and days often warm.

Of specific interest for the weathering in the chapel is condensation events. During our short field work period we did nor observe dew on the walls, and as can be seen from the diagram above the dew point is generally 3-4ºC below the room temperature. Since many signs of condensation events can be observed in the chapel (lime crusts and other patterns of small amounts of running water), it may be assumed that heavy condensation events do occur, probably mostly in autumn and spring. However, one cannot rule out the possibility that signs of running water along the walls may also be caused by precipitation, especially in the autumn period when the ground may reach saturation. Fractures in the basalt cliff would in this case form the drainage channels.

Heavy autumn rain for several consecutive days may also influence the stability of the blocks making up the basalt cliff. Although we do not know the reason why, it is a matter of fact that many large stone blocks have fallen from the cliff earlier - and after the chapel was built.

9 Stability and vegetation

Crack between basalt blocks in the roof of the chapel. Location of photo, appendix 1, no. A

Sharp basalt pieces within the above. Location of photo, appendix 1, no. B

Roots about to burst the basalt in the cliff to the east of the caves

Possible unstable basalt blocks in the cliff making up the roof of the chapel is probably the greatest risk to its preservation. As can be seen on the ground plan (page 7) the chapel is situated below a somewhat projecting part of the basalt cliff. On both sides large basalt blocks have fallen, a feature which is most notable between the entrance and the caves. The ground plan (page 7) and the photo to the right also shows how a large crack runs east-west along the whole nave - a crack representing the division line between basalt blocks and. It may seem that the crack is relatively stable at the moment: On plaster covering part of it there are only small fissures. However, since we don't know when this plaster was applied, it is impossible to use this observation as a "measure". Within the crack there are some very pointed and sharp smaller pieces of basalt which will fall if the crack widens more (se photo below).

Blocks to the south of the crack are, as mentioned earlier, supported by tuff strengthened by stone masonry. The outer facade masonry possibly also has a stabilising effect. Whereas the former masonry is in good shape, the facade masonry is rather weathered: Many stones have fallen and the mortar is disintegrating. Part of the reason for this is probably ivy-like creepers normally covering the facade (we cleared the facade of the creepers in order to be able to see it). On the other hand, the creepers may prevent rain washing out the mortar.

The reason why so many basalt blocks have fallen beside the chapel could be earthquakes, heavy rainfalls (as discussed in the previous chapter) and growing trees and roots. It is impossible at this stage to know in which way earthquakes may influence the situation, but in the near vicinity of the chapel there are many examples of roots bursting the basalt. An obvious measure to avoid root-bursting would have been to keep the vegetation down by cutting at least some of the trees. However, as some roots may keep blocks in place and cutting trees may increase the amount of water entering cracks and the general erosion, it is indeed not a straightforward measure. At the moment the only sensible measure is to monitor the relevant cracks and the general behaviour of the vegetation in order to learn more.

Right: Photo before clearing the facade of the chapel of ivy-like creepers below branches of trees covering the upper parts. Left: After clearing. Note the condition of the masonry; disintegrating mortar and missing stones, as well as a few cracks.

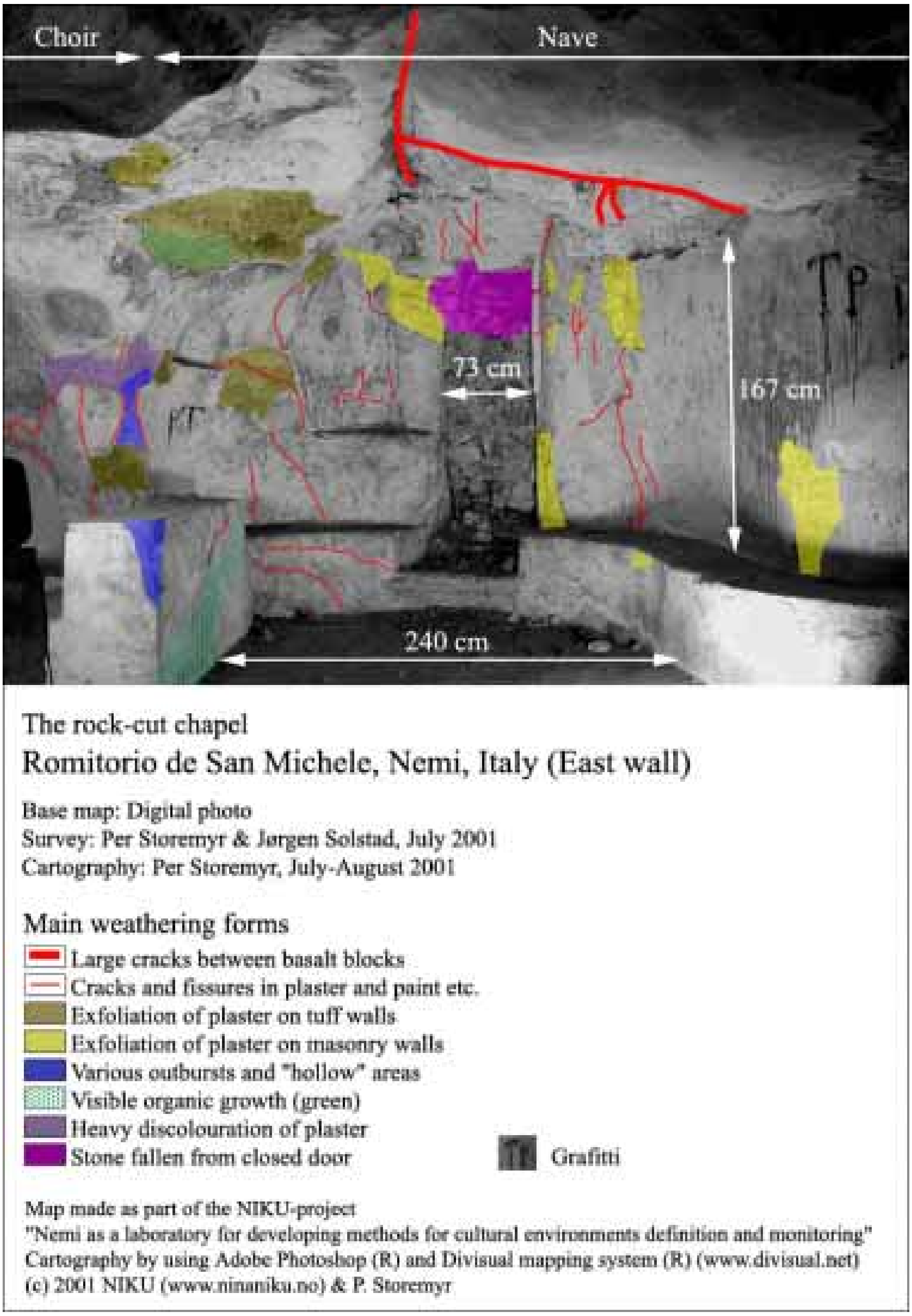
Securing basalt cliff by Nemi town gate in July 2001

The cliff above the chapel is not the only basalt cliff around Nemi having stability problems. Fallen blocks can be observed all over the place and a very notable example can be found at the high cliff just by the Nemi town gate.

During our field work period workers were stabilising the cliff by removing loose blocks and applying a metal net to avoid more blocks falling: The cliff is situated by the much used path leading down to Nemi lake and falling blocks may have disastrous consequences.

10 Weathering phenomena in the chapel

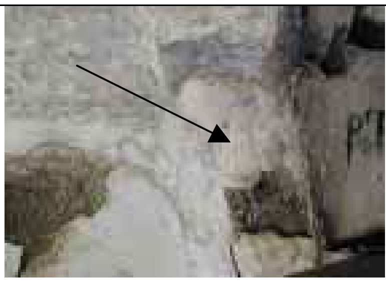
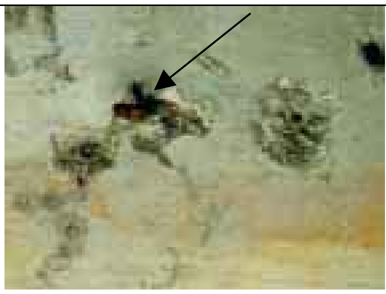
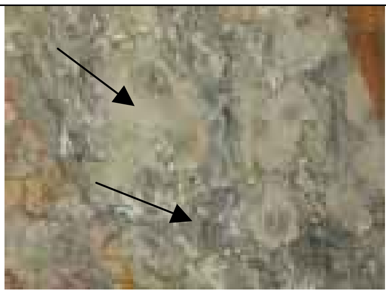
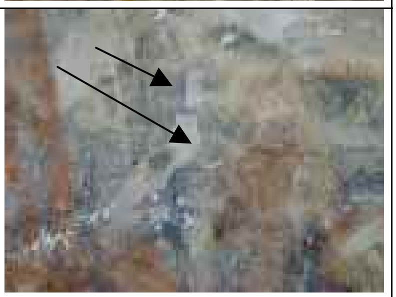
At first glance the chapel looks very damaged. Observing the situation more carefully, it appears that the irregular form of the chapel, many colour changes and a few large exfoliations of the plaster make the condition look worse than it is. Also the fact that the room is never cleaned and the decaying heap of leaves by the entrance (because the ground outside is half a meter higher than the chapel floor) adds to the "sad" appearance.



Map of main weathering forms on the east wall of the chapel

Below, some damages and weathering phenomena located on the map on the previous page (as well as phenomena related to the frescos) will be systematically described. "LOC." refers to picture location and can be found in appendix 1.

<table>
<tr><th>LOC.</th><th>PICTURE</th><th>DESCRIPTION</th></tr>
<tr><td>C</td><td></td><td rowspan="2">Cracks and fissures in plaster and paint.
Cracks and fissures in plaster and paint can be found all over the chapel, but especially related to areas which have other damages as well. They usually seem relatively harmless, except at places where they are connected to the large cracks between basalt blocks, and thereby to stability problems, as above the blocked door on the east wall (loc. C). A special feature is that many fissures are filled with recrystallised calcite (loc. D, se also sample 3, appendix 1). This calcite must come from the plaster and whitewash and indicates occasional very wet conditions in the chapel, either caused by condensation or water leaks through cracks in the basalt, or a combination. The Holy Family fresco has particularly many fissures with recrystallised calcite. The causes of the smaller, relatively harmless fissures can be everything from small-scale stability problems to hygric/thermal expansion and shrinkage.</td></tr>
<tr><td>D</td><td></td></tr>
<tr><td>E</td><td></td><td>Exfoliation of plaster on tuff-walls
This is the most significant damage in the chapel (except from large cracks described above). It occurs on tuff walls, especially on the east side, and in the part of the ceiling having tuff. At such places the tuff normally is covered with large amounts of what appears as salt efflorescences and salt crusts, but that upon closer examination mostly turns out to be cauliflower calcite crusts (samples 2 & 7, appendix 1). Unknown, complex salts can however also be found in such areas (sample 1). Again, the occurrence of calcite points to occasional very wet conditions in the chapel. Below the Holy Family fresco, as well as in parts of the roof it is evident that the exfoliation is a recurrent phenomenon, reappearing after repair measures. These areas are in other words specific problem areas. The causes must probably be sought in water drainage patterns.</td></tr>
<tr><td>F</td><td></td><td>Exfoliation of plaster on masonry walls
This is a phenomenon especially occurring close to the entrance (half of the Saints' Row fresco is influenced by it), and around the blocked door in the east wall. In the latter area it seems evident that the exfoliation is connected to fissures and cracks. Otherwise, its causes must be similar to those creating exfoliation of plaster on tuff-walls</td></tr>
</table>

G		**Various outbursts and hollow areas** These phenomena are connected to exfoliation of plaster on tuff-walls, as well as to fissures and cracks. Generally, the hollow areas represent exfoliating plaster not yet fallen from the walls.
H		**Visible organic growth** There is less visible organic growth in the chapel that one would have expected in such a moist environment. Although samples have not yet been analysed, it seems that green algae is the main constituent of the growth. It can especially be found on the ceiling, along the floor and on the altar marble elements. A special case is loc. H, where the growth appears as moss to the naked eye. However, analysis of sample 7 (appendix 1) shows that it is rather algae occurring on and within cauliflower calcite crusts.
I		**Outbursts around nails** This is a very peculiar damage form, occurring especially on the frescos in the choir. *Hundreds of nails have, for unknown reasons, been hammered into the plaster*, giving rise to outbursts upon rusting of the nails. There are few rusting nails remaining, implying that this damage form is no longer very active.
J		**Discoloration** Discoloration is the main weathering form of the otherwise very well-preserved frescos in the choir. The phenomenon also occurs on plastered tuff walls. On the frescos it appears as stable, grey areas, as if the pigments have been "washed" away only. At the moment we cannot explain this weathering phenomenon, but it would seem that it is connected to occasional very wet conditions, since the areas often have the form of "wet spots". It is probably not possible to get a grip on this weathering form without investigating the chapel in a moist period. Although the grey areas seem relatively stable, one cannot rule out the possibility that the discoloration phenomenon is a very active one, thus representing the main threat to the frescos.
K		
L		

M		**Flaking of whitewash and paint** This is a weathering form of very limited distribution. It occurs at a few places on the masonry wall close to the entrance and on the Saints' Row fresco, and is always followed by powdery salt efflorescences. However, the salt appears to be gypsum only and not more strongly hygroscopic ones (sample 10, appendix 1). The general absence of hygroscopic salts in the chapel may point in two directions: They might simply not be present, or the conditions might be too moist for them to frequently crystallise. Only complete salt analyses of the building materials (tuff, plaster) can give an answer to this question. A preliminary analysis of the tuff (sample 5) indicates that the salt content (anions) of the tuff is low.
N		**Light veils** Large parts of the Saints' Row fresco are covered by light, very thin veils of a material that visually appears to be calcite. It probably represent lime-rich water occasionally running down the wall, which again points to moist conditions in the chapel, either caused by condensation or rain water infiltration, or a combination. At a couple of places black letters (T & P) have been painted on the walls - and the black colour has run down. The origin of this kind of **graffiti** has not yet been explained.
O		**Fragments of whitewash on frescos** Whether the many fragments of whitewash on the frescos should be regarded as a damage can be discussed. It is however important to note that the removal of the whitewash appears not to have caused much mechanical damage to the frescos.

11 Discussion of major environmental risks

The major risks to the preservation of the chapel cannot be properly determined on the basis of our brief investigation only. Surveying of the near surroundings, the whole chapel and detailed mapping of the frescos, as well as long-term monitoring of the evolution of the damages would be needed before being able to state anything certain - and to give a prognosis for the future. However, without trying to interpret the main risks already at this stage, one would on the other hand not be able to carry out appropriate monitoring.

A prerequisite for further damage surveys and appropriate monitoring is a detailed map of the chapel and its near surroundings. This should not be too difficult and time-consuming to realise if a total station were put in use. By using a total station it would also be possible to make a three-dimensional representation of the area/chapel. However, one would have to partly clear the area of trees and bushes in order to be able carry out such a measured survey.

Although there is always a risk of *vandalism and theft* in an abandoned and rarely visited chapel like San Michele, the main risks are *environmental*, which may be defined as virtually uncontrollable geologic, biologic and climatic events and processes giving rise to various kinds of stability and weathering problems. The *causes* of these risks can rarely be controlled, but one may be able to control the *effects* of them, i.e. the effects they have on the chapel and its decoration. The effects of the risks that will be discussed below are connected to evolution of cracks and possible collapse of parts of the chapel, as well as to evolution of the many "minor" weathering processes.

EARTHQUAKES

We don't know if earthquakes are able to seriously disturb the basalt blocks of the cliff in which the chapel is situated. The only way to find out is to *ask local people if such phenomena have occurred in the Nemi area in the past*, as well as to *continuously monitor crack evolution by electronic loggers in and close to the chapel and compare with the seismic activity in the area*. It should be possible to get hold of seismic data from a regional station. Crack evolution could of course also have other reasons, as root bursting and climatic (seasonal variations, rainfall). Thus, interpretations also have to consider these (using climatic data from regional stations). Combating the possible disastrous effects of an earthquake could perhaps be done by securing the basalt cliff/blocks by special systems?

VEGETATION

There are several examples of roots bursting the basalt in the near vicinity of the chapel. Whether this is the case also with the *actual* basalt blocks making up the "roof" of the chapel has not been determined. Thus, *a very important aim of further field work should be to map the cliff, its cracks and trees/roots in a detailed manner and to regularly observe how the roots evolve*. Combating crack evolution due to root bursting could be done by regularly cutting the trees in question. However, one would first have to determine whether the actual roots also have a "consolidating" effect on the cliff/-blocks. If they have, removing them would demand applying man-made security measures instead.

The ivy-like creepers and other vegetation normally covering the facade of the chapel appear to partly contribute to the disintegration of the masonry. Perhaps the easiest way to control this growth is to make sure the facade is in good shape. This would imply a simple and inexpensive *restoration campaign*; removing all roots, repairing joints and cracks by lime mortar, putting fallen stones back in place and "plastering" the facade using the "pietra rasa" technique.

WATER INFILTRATION

It has been shown that the walls of the chapel occasionally must be very moist (due to the widespread occurrence of recrystallised calcite). This moisture might be connected to water infiltration in rainy periods or to heavy condensation events. Whether water infiltration is the main cause *can only be determined by observing the chapel and its surroundings during heavy rain*. On the one hand, one should look for signs of running water and particularly moist areas in the chapel itself, and on the other hand find out if specific drainage channels in the basalt cliff exist. Such observations should be regarded a very important part of a monitoring programme for the chapel.

Of specific interest is the behaviour of the cave to the east of the chapel during heavy rain. There are indications that it may occasionally fill with water, although this seems unlikely, given that the tuff in which the cave is situated is very porous. But again, the only way to find out is to observe the cave during a rainy period. The reason why it is important to find out is that the cave is situated just to the east of one of the most heavily repaired areas in the chapel (below and beside the Holy Family fresco). It could be that excessive moisture from the cave is at least partly responsible for the problems in this area.

If water collects in the cave, a way to get rid of the problem is to dig a drainage channel through the masses partly blocking its entrance. This would imply clearing the area of threes and bushes and undertake the excavation under archaeological surveillance. Controlling running water at other places around the chapel during heavy rain should also be considered.

CONDENSATION

Condensation in the chapel takes place when the temperature *on the walls* is below the dew point. It may give rise to colour changes, salt weathering and development of calcite crusts, as discussed earlier. In our case one would especially expect condensation to happen on very humid summer days and at times during the cold season. It is possible to *determine the condensation potential by monitoring the general room climate (temperature and relative humidity) in the chapel, as well as the temperature on selected walls*. According to experience this would remain a theoretical exercise if not simultaneously observing the walls of the chapel in typical seasons. Thus, *regular observation suggested above as part of a monitoring programme should also include looking for signs of condensation.*

Condensation typically occurs on *cold spots* in a building/structure. Thus, finding and monitoring these could be done by systematically measuring the wall surface temperatures in typical seasons or by applying an infrared camera.

It is difficult to avoid condensation events, but it can be done. A simple measure would be to install a door that could properly closed in main risk periods. However, this would imply to define the main risk periods, to design and install a door and to employ a caretaker.

BUSHFIRES

Bushfires frequently occur in the Nemi crater and a few years ago an area 2-300 m to the north-west of the chapel was hit (see picture on page 5). The question is what effect, if any, a bushfire would have on the chapel. The only effect we can think of is possible destabilisation of the basalt cliff due to burning of trees and roots. How bushfires may affect basalt cliffs should not be too difficult to check; one could simply *carefully observe what has happened at various places elsewhere in the Nemi crater*.

PRESSURE FROM SCREE MASSES

As mentioned earlier the blocked door in the east wall of the nave is almost completely blocked by scree masses on the outside, towards the cave. As shown on the map on page 18, this may have lead to a destabilisation of the masonry used to block the door - the upper part of the masonry has fallen in. A simple measure would be to relieve the pressure by removing the upper part of the scree masses.

VANDALISM

Vandalism is not really an environmental risk, but is nevertheless included here. A simple way to reduce the risk would be to repair the entrance gate: today it is "disturbed" by a half metre high decaying heap of leaves, making it impossible to close it properly. Removing these masses and applying a better lock would significantly improve the situation.

12 Monitoring the actual evolution of weathering forms

Above we have concentrated on environmental risks possibly causing various types of stability and weathering problems in the chapel. How these risks actually influence on plastered walls and frescos remains to be properly determined.

During the field work period, small areas for regular digital photographic monitoring of the evolution of damages on the frescos were established. The areas were selected "statistically", before we had a general overview of the damages in the chapel.[8] Many of the areas/photos can certainly be used as reference for further monitoring/photography of the frescos in order to be able to detect changes over time. However, as we now know the main damage forms, we should be able to supplement, if necessary, with other areas in which the typical forms occur. The most important phenomena to monitor is (see also chapter 10): 1) Colour changes, 2) Cracks without recrystallised calcite, 3) Cracks with recrystallised calcite, 4) Light veils, and 5) Flaking due to salts.

For purposeful monitoring of other weathering phenomena in the chapel, as for instance exfoliation of plaster and biological growth, various overview and detail photos will suffice. During the field work period the whole chapel were photographically documented. A special case is salt efflorescences and calcite crusts on tuff in areas where the plaster has exfoliated. Regularly observing the behaviour of these spots could lead to a greater understanding of why the plaster has exfoliated.

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[8] Selection of areas and photography were undertaken by Jørgen Solstad, Lars Erikstad and Vegard Bakkestuen. This work is reported separately

13 Summary of survey and monitoring proposals

Further survey and mapping of the chapel and its surroundings should include:

- Measured survey of the chapel, the cave(s) and the basalt cliff, if possible with a total station
- Mapping of geology (basalt blocks, cracks etc.) and vegetation around the chapel
- Mapping of materials, repairs and weathering forms in the whole chapel
- Specific mapping of stratigraphy and weathering forms on the frescos

Monitoring the environmental risks should be based on three different strategies:

- *Crack evolution* as a function of seismic activity, seasonal climate variations and the action of roots.
- *Climate monitoring* in the chapel and on the chapel walls (temperature and relative humidity) over a longer period of time (several years)
- *Direct observation* in typical seasons (spring, summer, autumn, winter) of possible water infiltration, condensation, vegetation evolution and the evolution of various weathering phenomena

Monitoring the actual evolution of weathering forms should be based on overview and detail photos, which should be taken c. once a year in the beginning and with longer intervals later.

14 Summary of simple conservation measures

Some simple conservation measures somewhat improving the condition of the chapel can be undertaken without further investigations:

- Regularly cleaning the floor and benches (also in order to be able to better observe if anything falls from the ceiling and walls over time)
- Repairing the entrance gate and removing masses outside it
- Removing scree masses outside the blocked door in the east wall of the nave
- Restoring the facade masonry

In addition several areas in which the plaster exfoliates, as well as hollow areas below plaster can be repaired and secured by lime mortar and lime mortar injections.

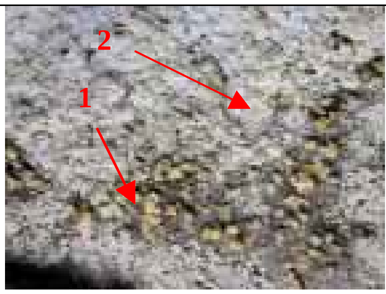
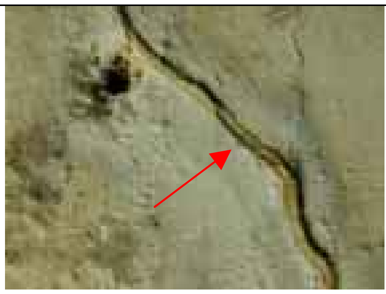
Other measures, for instance related to stability, climate control and various direct interventions on walls and frescos, cannot be undertaken before more is known about causes, actions and processes.

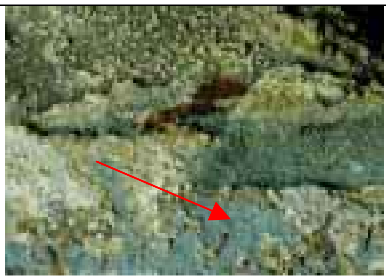
Appendix 1: Preliminary sample analysis and location of photos for description of damages

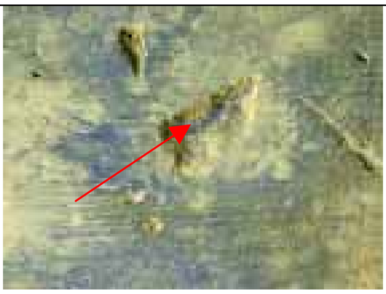
The three pictures to the left show location of samples taken (1-14) and location of photos used to describe damages (A-O)

On the next pages follow a preliminary sample analysis and suggestions for further analyses.

Damage description can be found as a separate chapter in the report.

Sample	Photo	Description and analyses	Further analyses (proposal)
1 and 2		1: Cauliflower crust on tuff (yellowish on picture). Large grain-masses in microscope, pinkish to greenish, almost isotrope. No effervescence. in 10% HCl, sol. in water - gives milkwhite solution. pH c. 8, Very much SO_2, Cl and NO_3. **Unknown salt**. 2: White, powdery mass. Small grains with high interference colours in microscope, effervesce in 10% HCl, pH c. 7, No SO_2, Cl or NO_3. Probably **calcite**	1: XRD
3		Hard, fine small crystals with high interference colours, effervesce in 10% HCl. Probably **calcite**.	
4		Mortar from blocked door. Not analysed	Full mortar analysis, also in order to check for cement (for "dating" the mortar)

5 and 6		5: Tuff "powder". None of the minerals effervesce in 10% HCl, traces of SO_2, Cl and NO_3 6: Mortar from area around "outburst" (had fallen down). Not analysed	5: XRD for mineralogy and full salt analyses for understanding the "background" soluble salt level. 6: Full mortar analysis
7		Very green layer on tuff and white crusts. Sample taken for microbiological analysis. The green layer is on and within a crust of **calcite** (tested in microscope and with HCl). There is also a white, powdery salt with the optical properties of **gypsum** in the area	Microbiological analysis
8		Cauliflower, relatively hard crusts on plaster/whitewash. Effervesce in HCl, probably **calcite**	
9	No picture	Large area with green, moss-like biological growth	Microbiological analysis
10		Powdery salt efflorescences below paint layers that are about to flake off. In the microscope the optical properties of the salt resembles **gypsum**.	Further salt analysis (microchemistry)

11		Small piece of plaster with paint from the Saint's Row. Under the stereo microscope it seems that the upper layer is more a crust than a paint layer, indicating **fresco technique**	Polished section, microscopy
12		Powdery salt efflorescences. In the microscope the optical properties of the salt resembles **gypsum**.	
13		Small piece of plaster with paint from the Crucifixion. Under the stereo microscope it seems that the upper layer is more a crust than a paint layer, indicating **fresco technique**	Polished section, microscopy
14		Small piece of plaster with blue paint from the Altar picture	Polished section, microscopy and pigment determination (in order to "date" the blue pigment)

Appendix 2: Forms for GIS-based monitoring of the chapel

A main objective of the project is to develop a GIS-based system for monitoring the monuments and cultural environments in the Nemi crater. A preliminary form for each object was worked out by NIKU before the field work. This form has been filled in below (table 1). Numbers in the form refer to ratings. Description of the ratings can be found in table 2 (in Norwegian).Project collaborators were also asked to suggest a more detailed form for the case studies undertaken. In table 3 a preliminary for this purpose has been suggested and filled in. It should be underlined that this form is meant as a starting point for discussions only. No attempt has been made to fit it into a GIS-system.

Table 1: Preliminary general form for each object. Explanations in Norwegian in table 2

Locality

Locality	Romitorio de San Michele
Object	Rock-cut chapel and related caves
Identity no.	?

Cultural environment

Cultural environment	Decorated chapel and undecorated caves cut into tuff layer in a basalt cliff
Condition	Possibly unstable basalt cliff in which the objects are situated. Rock slides occurred in the past. Heavy vegetation, large trees. No apparent regular management and care.
Found	?
Visibility	2
Vegetation rate	2
Interventions	No interventions lately

Object (general)

Condition object	2
Condition near surroundings	2
Accessibility	2
Conservation measures	Without further investigations: Cleaning, repairing entrance gate, removing various scree masses, restoring facade masonry and exfoliated areas in the chapel (with lime mortar)
Vulnerability	Medium?

Values

For the public	1
Knowledge (historical val.)	5

Visibility history

1944	?
1986	?
Satellite image	?

Table 2: Description of the form used in table 1 (in Norwegian)

lokalitet	lokalitetsnummer refererer til numrene i Lenzis artikkel i Nemi status quo? 2000. Diana tempelområdet gitt eget nummer (31).
objekt	refererer til en underinndeling, hver lokalitet kan inneholde flere objekter.
id-nummer	refererer til det italienske register nummer.
kulturmiljø	hvert kulturmiljø kan omfatte flere lokaliteter og objekter og det tilknyttede landområde. Kontekst.
miljø-tilstand	Skjøtselstilstand, bevaringstilstand til det enkelte kulturmiljø beskrives. Interaksjonen mellom miljøet og kulturminnet.Blant annet botanisk beskrivelse.
gjenfunnet 0/1	0 = ikke gjenfunnet, 1=gjenfunnet
synlighet 1,2,3	1= godt synlig lett gjenfinnelig lokalitet og objekt også for et utrent øye 2= middels synlig lokalitet og objekt, delvis overgrodd, delvis borte av annen grunn - angi % 3= ikke-synlig for utrent øye
gjengroing/biologisk påvirkning	1= ikke påvirket av gjengroing 2= klart truet av gjengroing angi % 3= helt overgrodd objekt eller lokalitet.
inngrep	Tekniske inngrep som jordbruk, samferdsel, nybygging,annet.
tilstand objekt	1= god tilstand, stabile konstruksjoner/struturer. 2= middels, under synlig nedbryting, for eksempel enkelte løse sten i mur, infiltrerende vegetasjon o.s.v. 3= dårlig bevaringsgrad, sterkt forvitrende konstruksjon, evt. sterkt påvirket av vegetasjon,sopp o.s.v.
tilstand nærområde	1= god tilstand, fritt for truende vegetasjon og inngrep, søppel m.m.. 2= middels god tilstand, truende vegetasjon, inngrep på gang, noe søppel m.m. 3= dårlig tilstand, gjengrodd så sammenhengen ikke er forståelig for utrent øye, henlagt søppel, andre mulige inngrep.
tilgjengelighet	1= god tilgjengelighet, adkomst veg/sti, skilting, merket på almen tilgjengelig kart. 2= middels god tilgjengelighet, opmerksomhet påkrevet, en må gå noe ut i lende fra veg/sti, ikke skiltet, markert på almen tilgjengelig kart 3= vanskelig tilgjengelig, opparbeidet veg sti finnes ikke, ikke skilt, ikke merket på almen tilgjengelig kart.
skjøtsel/ konservering	
sårbarhet	geologi,geografi,avstand til tilgjengelighet, terreng, avstand til sti, inngrep, vegetasjon.
formidlingsverdi 0/1	
kunnskapsverdi 1-5	
synlig 1944	0= ikke synlig 1= synlig
synlig 1986	0= ikke synlig 1= synlig
synlig satelittbilde	0= ikke synlig 1= delvis synlig 2= godt synlig 3= endring observert
ballonbilder	
bakkebilder	
lupenivå/ mikroskopi	

Table 3. Proposal for detailed form for building construction elements and decoration

Building construction elements

Elements	**Materials**	**Damage rate***	**Main risk factors**	**Monitoring**	**Conservation measures**	**Comment**
Roof	Basalt cliff/blocks	2	Earthquake, vegetation	Crack	Further studies	Stability of roof uncertain
Facade	Stone masonry	2	Vegetation, moisture	Photo	Repair masonry	
Interior walls	Plastered/white-washed tuff and stone masonry	3	Moisture	Photo, indoor climate	Further studies, repair exfoliated areas	Many large exfoliated areas
Floor	Peperino stone	1	Moisture,		-	
Entrance	Stone masonry portal and iron bar gate	2	Vegetation	Photo	Remove earth and repair door	Gate cannot be locked properly

* Damage rates: 1=Very little damaged, stable situation; 2=Some visible, active damages; 3) Very damaged, many active weathering processes

Decoration etc.

Feature	**Materials**	**Damage rate**	**Main risk factors**	**Monitoring**	**Conservation measures**	**Comment**
Fresco Saints' Row	Fresco painting	2	Moisture	Photo, climate	Further studies	Half of the fresco have disappeared
Fresco Crucifixion	Fresco painting	2	Moisture	Photo, climate	Further studies	Colour changes
Fresco Holy Family	Fresco painting	2	Moisture	Photo, climate	Further studies	Colour changes
Altar	Marble and granite elements, masonry and painting	1	Moisture	Photo	-	A bit of algae
Stucco Angels	Unknown stucco	2	Moisture	Photo	-	Largely gone

* Damage rates: 1=Very little damaged, stable situation; 2=Some visible, active damages; 3) Very damaged, many active weathering processes

Specific monitoring (very preliminary form!!!!)

Feature	**Type**	**Established (date)**	**Interval**	**Visits and maintenance**	**Comments on results**	**Reference/link to reports**
Cracks in basalt roof	Loggers		Daily			
Indoor climate	Loggers	July 2001	Hourly	July 2001	One week monitoring.	Storemyr (2001)
Overview exterior	Photo	July 2001	Yearly			Storemyr (2001)
Overview interior	Photo	July 2001	Yearly			Solstad & Storemyr
Details frescos	Photo	July 2001	Yearly			Solstad & Storemyr
Direct observation	Human eyes!	July 2001	Seasonal			Storemyr (2001)