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

Case study of Romitorio of S. Michele
22-26 July 2001

The presbytery of Romitorio of San Michele with painted walls and altar

Field report to Norwegian Institute for Cultural Heritage Research (NIKU)

by

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Preface

This is a field report summarising work done at the Romitorio of S. 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 shrine can be found. The report does not aim at a comprehensive understanding of the shrine and its history, and, awaiting results of further 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 Helliksen, Anne-Cathrine Flyen, Lars Erikstad and Vegard Bakkestuen.

Field work was supported by NIKU and (for the author) the Restoration Workshop of Nidaros Cathedral, Norway (www.nidarosdomen.no). Writing of the report was supported by Expert-Center für Denkmalpflege, Zürich (www.ecd.ethz.ch)

Zürich in October 2001
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1 Introduction

This report deals with the construction, materials and weathering of the abandoned, small rock-cut (grotto shrine) Romitorio of S. Michele", situated just below the town of Nemi and above the Nemi crater lake in the Alban Hills near Rome. The shrine was chosen as a case study in the NIKU1-project "Nemi as a laboratory for developing methods for cultural environments definition and cultural heritage monitoring".2

The objective of the case study was to survey the shrine 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 shrine 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 NIKU-project.

Field work was undertaken over 5 days in July 2001. Simultaneously, other project collaborators established areas for digital photographic monitoring of the frescos in the shrine and surveyed other sites around Lago de Nemi (mainly the large Roman Villa, which is currently under archaeological excavation3). Moreover, the frescos were investigated art historically by Olaf Steen and Kirsti Gulowsen. Names and terms describing the shrine are taken from their report.4

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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
4 Steen & Gulowsen (2001): The Romitorio of S. Michele by Nemi in the Colli Albani. Unpub. rep. to NIKU
Due to the short field work period, and the fact that virtually nothing was known in advance about the building and restoration history of the shrine, the survey had to be limited to selected parts of it. Thus, in addition to the shrine's near surroundings, a relatively detailed survey was made of the east wall of the interior, as well as of parts of the frescos.

2 Location of the shrine

The shrine 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. Although there is no volcanic activity at the moment, the Colli Albani volcano is not completely inactive. However, its eruptive phases seem to occur with very long intervals. Earthquake activity occurs, as exemplified by the 1995 Rome quakes.

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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6 Up to 3.9 on the Richter scale, see http://www.geo.mtu.edu

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Lago de Nemi as seen from Nemi town towards Genzano in the southwest

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 shrine. Is the structure representing the shrine?

(Photo of copy of painting in Museo de Nave Romani by Nemi)

3 General description of the shrine

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

Although having a rather irregular outline, it is possible to divide the shrine in a main room and a smaller presbyterium, which are separated by low masonry walls (a chancel screen). The main axis is about N-S, with the entrance, or portal, on the south side. The length (N-S) is about 8.8 m, whereas the main room is some 7.6 m broad (E-W) and the height generally 2-3 m. The room being rather roughly cut into the tuff, there is usually a fluid transition between walls and ceiling.

The presbyterium has a main apse, two lateral apsidioles and two niches, as well as a large 19th C altar, partly made from reused Roman elements. 15th century frescos can be found in two of the apses, depicting the “Crucifixion” (W, dated to 1480 according to the dedicatory inscription) and the “Virgin Mary and child” (E). There are also smaller frescos in the niches, as well as decorations elsewhere in the shrine that are now (partly) covered by whitewash. In the main room a fresco (“Saints and Angel”) can be found on the SE semi-circular masonry wall by the entrance. The fresco is, according to Steen and Gullowsen, of higher quality than the others and can be dated to the early 16th C. The semi-circular masonry wall was probably made to strengthen the tuff within it, preventing a large basalt block making up part of the ceiling to fall. A masonry bench also runs along this wall. Another main

7 Steen & Gullowsen (2001), op.cit.
Left:
The east side of the main room

Below:
Very rough sketch of the ground plan of the shrine and its near environment
feature of the east side of the main room is a now blocked door leading to a man-made cave just beside the shrine (see below). On the other side of the entrance there is no such masonry wall, and although there are some niches-like structures and several unexplained holes in the walls, the west side of the main room is generally simpler than the east one.

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

The exterior of the shrine 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 shrine

The cave(s) on the east side of the shrine are also difficult to detect at first glance because of vegetation and fallen basalt blocks. However, it would seem that the door from the shrine 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 lies on almost exactly the same level as that of the shrine. Horizontal "lines" of salt efflorescence indicate that the cave is (or was) occasionally filled with water. This may seem reasonable because the fallen basalt blocks and debris outside may prevent rain water to escape easily. It is on the other hand hard to believe that the porous tuff would allow larger quantities of water to collect.

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 obvious connection to the shrine indicates however that they might represent a retreat for persons being attached to the shrine.
5 Survey of construction materials

The east wall of the shrine 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.
The whole presbyterium and most parts of the main room have plastered tuff walls, but in the south-eastern part of the main room 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 shrine, 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.

Benches in the main room are made of plastered stone masonry and covered by slabs of Peperino stone, a pyroclastic stone (from a mudflow) extracted from several quarries in the Colli Albani and widely used from the Roman times until today.8 Finely worked slabs of Peperino stone are also found on the floor, on the stone masonry separating presbyterium and main room, as well as around the door leading to the cave and on small benches below the east and west apses of the presbyterium.

The altar (see 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 quarries in Egypt's Eastern Desert, or a stone extracted much later at for instance Sardinia or elsewhere.

6 Frescos and overpaintings

The three 15th and 16th C. frescos appear to be the oldest visible paintings in the shrine. 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 (giornate). However, it would seem that there is a difference between the two frescos in the presbyterium and the one in the main room. The latter painting is more "vigorous" - a feature that can be observed especially on the faces of the figures. Moreover, visual observation shows that the paint is a bit "layer-like" on the main room fresco („Saints and Angel“). Thus, these features may indicate that the paintings have been executed by different painters.9


9 See also Steen & Gullowsen (2001), op.cit.
However, it should be considered that the main room painting is executed on plastered masonry and situated close to the entrance, whereas the presbyterium paintings can be found on plastered tuff in the inner part of the shrine where the conditions appear to be moister. This might have been the situation also when (and after) the paintings were executed, implying that the presbyterium 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 presbyterium paintings are more strongly marked by loss or alteration of pigments than the main room 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.

It is difficult to say when the whitewash and overpaintings were stripped off the frescos, but one would assume it to be a rather late measure.
Above: Comparison between heads: the „Crucifixion“ fresco (left) and the „Saints and Angel“ fresco (right).

Middle: The yellowish line above the „Crucifixion“ fresco is painted on whitewash having earlier covered also the fresco.

Below: Detail from the north side of the „Crucifixion“ fresco 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 aiming to understand the hitherto largely unknown restoration history of the shrine. In addition to the two known whitewashing campaigns after the 15th-16th century, there are many evidences of plaster repairs, as shown on the map below.
Large plaster repairs are particularly evident on the part of the ceiling carved in tuff, as well as on the east wall of the presbyterium and adjacent areas in the main room. 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 main room must have been a rather recent measure, probably undertaken well after the shrine 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 shrine. 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 the whitewash covering the frescos off, as well as and some of the plaster repairs are restoration measures of the 19th or 20th century (perhaps undertaken simultaneously to the proposed construction of the altar in the 19th century10).

In order to understand the restoration history of the shrine, the archives of the Soperintendeza should be searched. Moreover, local people should be considered an important information source. Also, various repair mortars could be analysed with regard to possible cement content. In order to confirm the age of the altar, its painting with strong blue colours could be analysed with regard to the blue pigment. In addition, one should look for more inscriptions. And what does the year 1963 mean? This year has been inscribed at several places, especially on the altar.

The painting of the frescos in the 15th-16th century shows that the use of the shrine was at a heyday at this time. But does this mean that it is a Renaissance shrine? I consulted building archaeologist Øystein Ekroll and architect Arne Gunnarsjaa on this matter. After having seen pictures of the shrine, both of them got the feeling that it is much older, rather dating to the early Middle Ages, especially because of the rough outline. And why is the name of the shrine 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 shrine.

8 Climatic conditions

Before describing the damages and weathering phenomena in and around the shrine, 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.),12 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 1200-1300 mm and there is on average one day a year with a bit of snow. The main wind direction is south-westerly.

10 Steen & Gullowsen (2001), op.cit.
11 Both with The Restoration Workshop of Nidaros Cathedral
12 All climate data from the Velletri station, 1921-1966 period, see Caputo et. al. (1974) (op.cit.)
Although the shrine 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 within which it is situated.

In the fieldwork period, during which the weather was warm and sunny (max. c. 30ºC), we recorded temperature and relative humidity in the shrine 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 shrine is condensation events. During our short field work period we did not 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 shrine (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 shrine was built (see also later).
9 Stability and vegetation

Possible unstable basalt blocks in the cliff making up the roof of the shrine are probably the greatest risk to its preservation. As can be seen on the ground plan (page 7) the shrine 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 show how a large crack runs east-west along the whole main room - a crack representing the division line between large basalt blocks. 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 time-scale measure. Within the crack there are some very pointed and sharp smaller pieces of basalt which may fall if the crack widens more (see photo).

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 shrine could be earthquakes, heavy rainfalls (as discussed in the previous chapter) and growing trees and roots. It is impossible at this stage to know how earthquakes may influence the situation, but in the near vicinity of the shrine 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, as well as 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.
The cliff above the shrine 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 shrine

At first glance the shrine looks very damaged. Observing the situation more carefully, it appears that the irregular form of the shrine, 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 shrine floor) adds to the “sad” appearance.

Map of main weathering forms on the east wall of the shrine
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>
<thead>
<tr>
<th>LOC.</th>
<th>PICTURE</th>
<th>DESCRIPTION/INTERPRETATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td><img src="image" alt="Cracks and fissures in plaster and paint." /></td>
<td>Cracks and fissures in plaster and paint. Cracks and fissures in plaster and paint can be found all over the shrine, 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, 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, see also sample 3, appendix 1). This calcite may come from the plaster (although one cannot rule out the tuff as a source) and indicates occasional very wet conditions in the shrine, either caused by condensation or water leaks through cracks in the basalt, or a combination. <em>The „Virgin Mary and Child“ fresco has 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.</em></td>
</tr>
<tr>
<td>D</td>
<td><img src="image" alt="Exfoliation of plaster on tuff-walls" /></td>
<td><strong>Exfoliation of plaster on tuff-walls</strong> This is the most significant damage in the shrine (except from large cracks described above). It occurs on tuff walls, especially on the east side, and in the part of the ceiling made from tuff. At such places the tuff is normally 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 &amp; 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 shrine. Below the „Virgin Mary and Child“ 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>E</td>
<td><img src="image" alt="Exfoliation of plaster on masonry walls" /></td>
<td><strong>Exfoliation of plaster on masonry walls</strong> This is a phenomenon especially occurring close to the entrance (half of the „Saints and Angel“ 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 causing exfoliation of plaster on tuff-walls.</td>
</tr>
</tbody>
</table>

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### 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.

### Visible organic growth

There is less visible organic growth in the shrine than 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.

### Outbursts around nails

This is a very peculiar damage form, occurring especially on the frescos in the presbyterium. 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.

### Discoloration

Discoloration is the main weathering form of the otherwise very well-preserved frescos in the presbyterium. 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 shrine 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 a main threat to the frescos. And could it also be connected to biogenic processes?
| 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 hygroscopic ones (sample 10, appendix 1). The absence of hygroscopic salt efflorescences in the shrine 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 | 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 represents lime-rich water occasionally running down the wall, which again points to moist conditions in the shrine, either caused by condensation or rain water infiltration, or a combination. |
| 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. |

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.

### 11 Discussion of major environmental risks

The major risks to the preservation of the shrine cannot be properly determined on the basis of our brief investigation only. Surveying of the near surroundings, the whole shrine 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 shrine 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/shrine. 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 shrine like S. 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 hardly be controlled, but one may be able to control the effects of them, i.e. the effects they have on the shrine 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 shrine, 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 shrine 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 shrine 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 shrine. Whether this is the case also with the actual basalt blocks making up the "roof" of the shrine has not yet 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 shrine 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 (with pozzolana, if historically correct), 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 shrine occasionally must be very moist (due to the widespread occurrence of recrystallised calcite). This moisture might be connected to water infiltration in rainy
periods and/or to heavy condensation events. Whether water infiltration is the main cause can only be determined by observing the shrine and its surroundings during heavy rain. On the one hand, one should look for signs of running water and particularly moist areas in the shrine 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 shrine.

Of specific interest is the behaviour of the cave to the east of the shrine 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 shrine (below and beside the “Virgin Mary and Child“ 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 shrine during heavy rain should also be considered.

**CONDENSATION**

Condensation in the shrine takes place when the temperature on the walls is below the dew point. It may give rise to, for instance, 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 shrine, 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 shrine 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 200-300 m to the north-west of the shrine was hit (see picture on page 5). The question is what effect, if any, a bushfire would have on the shrine. 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 main room 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 decaying heap of leaves half a metre high, 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 shrine. How these risks actually influence 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 randomly, before we had a general overview of the damages in the shrine. 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) Veils, and 5) Flaking due to salts.

For purposeful monitoring of other weathering phenomena in the shrine, as for instance exfoliation of plaster and biological growth, various overview and detail photos will suffice. During the field work period the whole shrine was 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.

13 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 shrine and its surroundings should include:

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

It must be underlined that this proposal is based on the idea of using the shrine for research purposes, in addition to aid its conservation. A simpler programme could be envisaged if the research perspective is left out.

14 Summary of simple conservation measures

Some simple conservation measures improving the condition of the shrine 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 main room
- Restoring the facade masonry

In addition, several areas in which the plaster exfoliates, as well as hollow areas underneath 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 actually going on.
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 in a separate chapter in the report.
Analyses

Analyses were undertaken by stereo microscopy, polarisation microscopy (oil) and where necessary chemical tests (dissolution in water, pH, effervescence in 10% HCl, Merckoquant "teststrips" for sulphate, chloride and nitrate)

<table>
<thead>
<tr>
<th>Sample</th>
<th>Photo</th>
<th>Description and analyses</th>
<th>Further analyses (proposal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 and 2</td>
<td><img src="image1" alt="Photo" /></td>
<td>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 SO₄, Cl and NO₃. <strong>Unknown salt.</strong>&lt;br&gt;2: White, powdery mass. Small grains with high interference colours in microscope, effervesce in 10% HCl, pH c. 7, No SO₄, Cl or NO₃. Probably <em>calcite</em></td>
<td>1: XRD</td>
</tr>
<tr>
<td>3</td>
<td><img src="image2" alt="Photo" /></td>
<td>Crust along crack. Hard, fine small crystals with high interference colours, effervesce in 10% HCl. Probably <em>calcite</em>.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td><img src="image3" alt="Photo" /></td>
<td>Mortar from blocked door. Not analysed</td>
<td>Full mortar analysis, also in order to check for cement (for &quot;dating&quot; the mortar)</td>
</tr>
</tbody>
</table>
| 5 and 6 | 5: Tuff "powder". None of the minerals effervesce in 10% HCl, traces of SO₄, Cl and NO₃.  
6: Mortar from area around "outburst" (had fallen down). Not analysed.  
5: XRD for mineralogy. Soluble 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 resemble gypsum.  
Further salt analysis (microchemistry) |
<table>
<thead>
<tr>
<th></th>
<th>Small piece of plaster with paint from the „Saints and Angel“ fresco. Under the stereo microscope it seems that the upper layer is more a crust than a paint layer, indicating <strong>fresco technique</strong></th>
<th>Polished section, microscopy</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Powdery salt efflorescences. In the microscope the optical properties of the salt resembles <strong>gypsum</strong>.</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>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 <strong>fresco technique</strong></td>
<td>Polished section, microscopy</td>
</tr>
<tr>
<td>14</td>
<td>Small piece of plaster with blue paint from the Altar picture</td>
<td>Polished section, microscopy and pigment determination (in order to check if the pigment is one with typical use periods)</td>
</tr>
</tbody>
</table>
Appendix 2: Forms for GIS-based monitoring of the shrine

A main objective of the (continuation 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

<table>
<thead>
<tr>
<th>Locality</th>
<th>Romitorio de S. Michele</th>
</tr>
</thead>
<tbody>
<tr>
<td>Object</td>
<td>Rock-cut shrine and related caves</td>
</tr>
<tr>
<td>Identity no.</td>
<td>?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cultural environment</th>
<th>Decorated shrine and undecorated caves cut into tuff layer in a basalt cliff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condition</td>
<td>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.</td>
</tr>
<tr>
<td>Found</td>
<td>?</td>
</tr>
<tr>
<td>Visibility</td>
<td>2</td>
</tr>
<tr>
<td>Vegetation rate</td>
<td>2</td>
</tr>
<tr>
<td>Interventions</td>
<td>No interventions lately</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Object (general)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Condition object</td>
<td>2</td>
</tr>
<tr>
<td>Condition near surroundings</td>
<td>2</td>
</tr>
<tr>
<td>Accessibility</td>
<td>2</td>
</tr>
<tr>
<td>Conservation measures</td>
<td>Without further investigations: Cleaning, repairing entrance gate, removing various scree masses, restoring facade masonry and exfoliated areas in the shrine (with lime mortar)</td>
</tr>
<tr>
<td>Vulnerability</td>
<td>Medium?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Values</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>For the public</td>
<td>1</td>
</tr>
<tr>
<td>Knowledge (historical val.)</td>
<td>5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Visibility history</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1944</td>
<td>?</td>
</tr>
<tr>
<td>1986</td>
<td>?</td>
</tr>
<tr>
<td>Satellite image</td>
<td>?</td>
</tr>
</tbody>
</table>
Table 2: Description of the form used in table 1 (in Norwegian)

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Objekt</td>
<td>Refererer til en underinddelning, hver lokalitet kan inneholde flere objekter.</td>
</tr>
<tr>
<td>Id-nummer</td>
<td>Refererer til det italienske register nummer.</td>
</tr>
<tr>
<td>Kulturmiljø</td>
<td>Hvert kulturmiljø kan omfatte flere lokaliteter og objekter og det tilknyttede landområde. Kontext.</td>
</tr>
<tr>
<td>Gjenfunnet 0/1</td>
<td>0 = ikke gjenfunnet, 1=gjenfunnet</td>
</tr>
</tbody>
</table>
| 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/strutter.  
|                | 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, opparbeidet veg sti finnes ikke, andre mulige inngrep. |
| Tilstand nærområde | 1= god tilstand, fritt for truende vegetation og inngrep, søppel m.m..  
|                | 2= middels god tilstand, truende vegetation, 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 tilgjengelighet kart.  
|                | 2= middels god tilgjengelighet, opmerksomhet påkrevet, en må gå noe ut i lende fra veg/sti, ikke skiltet, markert på almen tilgjengelighet kart |
|                | 3= vanskelig tilgjengelighet, opparbeidet veg sti finnes ikke, ikke skilt, ikke merket på almen tilgjengelighet kart. |
| Skjøtsel/konserving |                                                                                                                                  |
| Sårbarhet      | Geologi, geografi, avstand til tilgjengelighet, terreng, avstand til sti, inngrep, vegetation.                                                                                      |
| Formidlingsverdi 0/1 |                                                                                                                                  |
| Kunnskapsverdi 1-5 |                                                                                                                                  |
| Synlig 1944    | 0= ikke synlig  
|                | 1= synlig                                                                                                                          |
| Synlig 1986    | 0= ikke synlig  
|                | 1= synlig                                                                                                                          |
| Synlig satellittbilde | 0= ikke synlig  
|                | 1= delvis synlig  
|                | 2= godt synlig  
|                | 3= endring observert                                                                                                                |
| Ballonbilder   |                                                                                                                                  |
| Bakkebilder    |                                                                                                                                  |
| Lupenivå/mikroskopi |                                                                                                                                  |
### Building construction elements

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

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

### Decoration etc.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Materials</th>
<th>Damage rate</th>
<th>Main risk factors</th>
<th>Monitoring</th>
<th>Conservation measures</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresco Saints and Angel</td>
<td>Fresco painting</td>
<td>2</td>
<td>Moisture</td>
<td>Photo, climate</td>
<td>Further studies</td>
<td>Half of the fresco have disappeared</td>
</tr>
<tr>
<td>Fresco Crucifixion</td>
<td>Fresco painting</td>
<td>2</td>
<td>Moisture</td>
<td>Photo, climate</td>
<td>Further studies</td>
<td>Colour changes</td>
</tr>
<tr>
<td>Fresco Virgin Mary and Child</td>
<td>Fresco painting</td>
<td>2</td>
<td>Moisture</td>
<td>Photo, climate</td>
<td>Further studies</td>
<td>Colour changes</td>
</tr>
<tr>
<td>Altar</td>
<td>Marble and granite</td>
<td>1</td>
<td>Moisture</td>
<td>Photo</td>
<td></td>
<td>A bit of algae</td>
</tr>
<tr>
<td>Stucco Angels</td>
<td>Unknown stucco</td>
<td>2</td>
<td>Moisture</td>
<td>Photo</td>
<td></td>
<td>Largely gone</td>
</tr>
</tbody>
</table>

* 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!!!!)

<table>
<thead>
<tr>
<th>Feature</th>
<th>Type</th>
<th>Established (date)</th>
<th>Interval</th>
<th>Visits and maintenance</th>
<th>Comments on results</th>
<th>Reference/link to reports</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cracks in basalt roof</td>
<td>Loggers</td>
<td>Daily??</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indoor climate</td>
<td>Loggers</td>
<td>July 2001</td>
<td>Hourly</td>
<td>July 2001</td>
<td>One week monitoring</td>
<td></td>
</tr>
<tr>
<td>Overview exterior</td>
<td>Photo</td>
<td>July 2001</td>
<td>Yearly</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overview interior</td>
<td>Photo</td>
<td>July 2001</td>
<td>Yearly</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Details frescos</td>
<td>Photo</td>
<td>July 2001</td>
<td>Yearly</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct observation</td>
<td>Human eyes!</td>
<td>July 2001</td>
<td>Seasonal</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>