

TECHNICAL ANALYSIS REPORT

Investigation of the phases of construction of the church. In situ study using observation of surfaces and stereo-microscopic analysis to arrive at a preliminary classification of the mortar types and their distribution within the various phases of construction and decoration of the church.

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Conservation and Documentation of the Wall Paintings at the Red Monastery, Sohag.

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Photographs showing locations from which samples were collected

Our ref. Z-30

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Re. Red Monastery. Investigation of the phases of construction of the church. In situ study using observation of surfaces and stereo-microscopic analysis to arrive at a preliminary classification of the mortar types and their distribution within the various phases of construction and decoration of the church.

1. Materials and methods

The mission at the Monastery to study the various phases of construction and decoration of the church was carried out between 11 and 14 April 2008. The study was carried out by means of careful macroscopic (autoptic) investigations, sampling and analysis using a portable stereo-microscope. In several cases, observations were made together with Luigi De Cesaris and his team, sometimes leading to the opening of test holes in the plaster and masonry in the form of “stratigraphic steps” and “wedges”.

The main aim of the mission was to define, even in a preliminary manner, the mortar types used in the masonry of the church (bedding mortar for the bricks) and the plaster types on which the wall paintings were executed. Observations were made both outside and in certain areas inside the building.

In some cases (for example, the lateral doorway in the north west side) the paint layers and associated preparatory layers were also examined.

The information gathered over the past few years as a result of the contribution of various professional figures and, in particular, the continuous study of the accumulated layers of paint and plaster during restoration operations, have enabled us to formulate a chronological model of the various periods of work on the church.

Therefore, during this phase we decided to evaluate the appropriateness of the model formulated by means of an extensive study of materials using simple yet effective techniques to achieve this pre-established aim. The mortar used in the masonry (to bed the bricks of the perimeter walls of the building and mortar types taken from various areas of the *prothesis*) and the original finishing plaster were compared with each other as well as with the mortar used during more recent restoration work of a structural or decorative nature.

Finally, the background knowledge accumulated as a result of processing and interpreting the analyses carried out in recent years has enabled a comparison to be made with the materials used in the painting cycles of the apse.

The results of the analyses are set out in detail as separate paragraphs for the various areas from which samples were collected. Each paragraph describes the characteristics of the sampling area and the results of stereo-microscopic examination of the samples collected. Photographs of the locations from which samples were collected are appended to this report.

A final section is dedicated to the interpretation of all the results obtained from the processing and correlation of the information gathered during the in situ study and the examination of each sample.

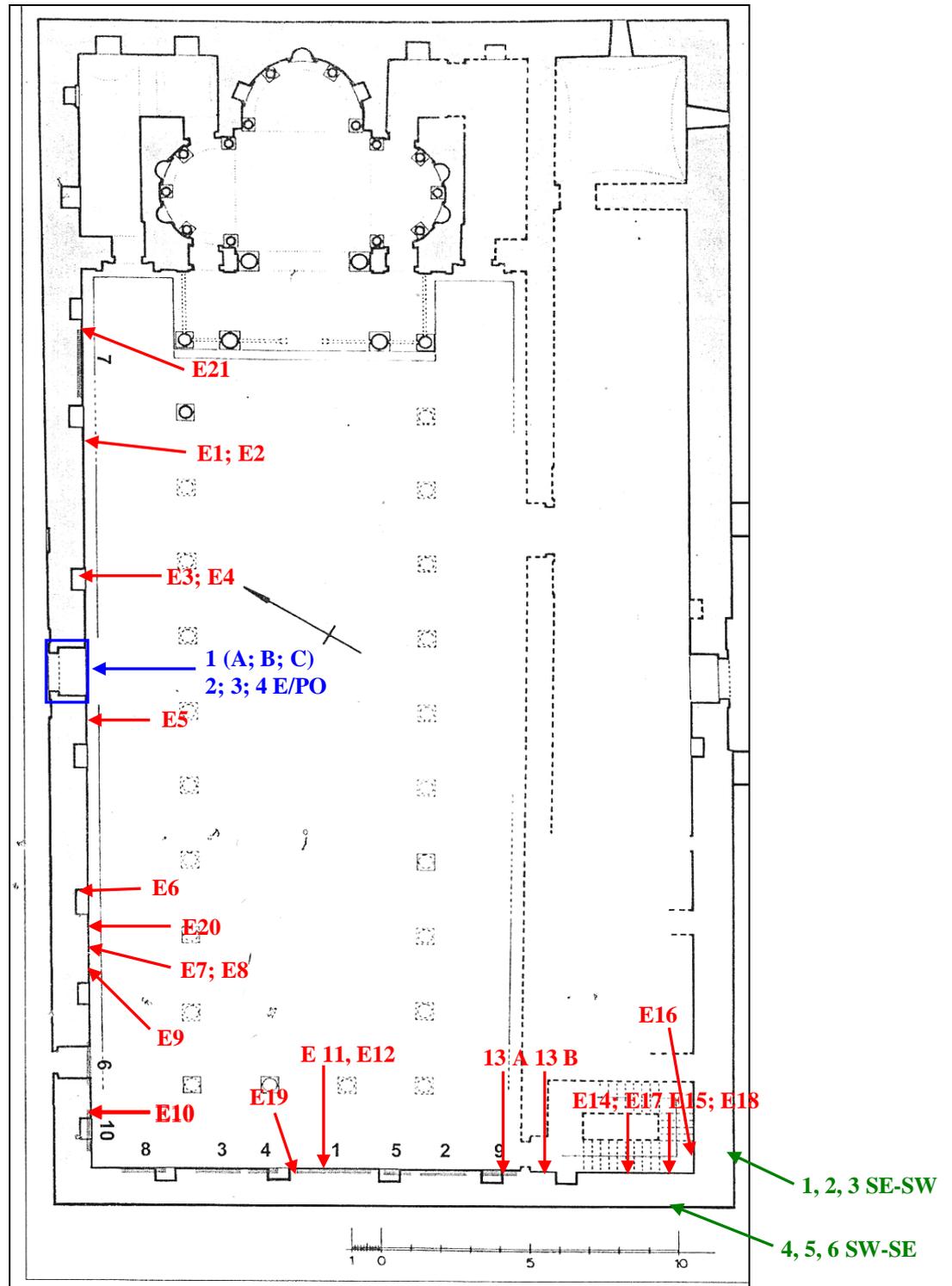
Rome 29 September 2008

Dr. Domenico Poggi

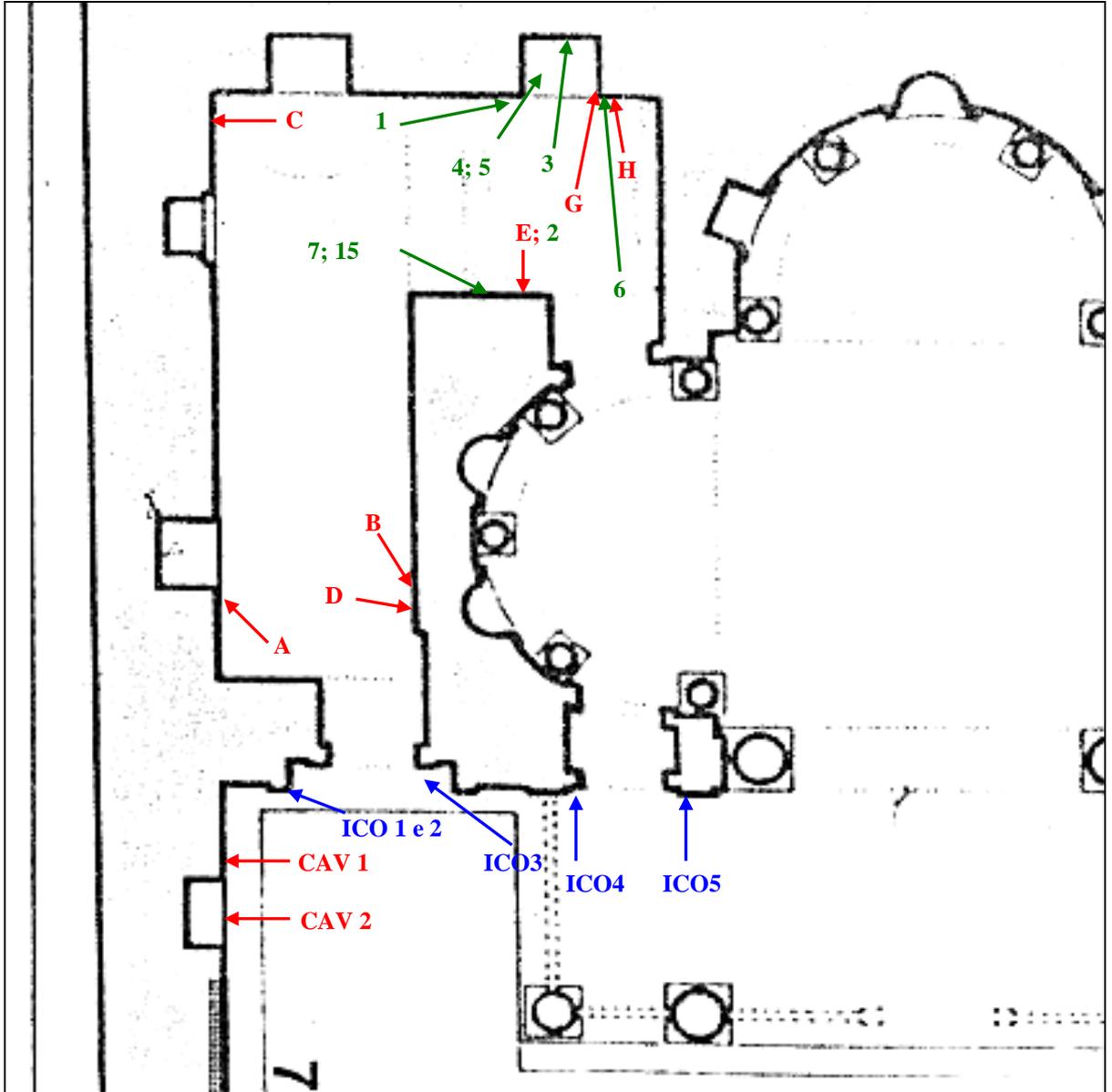


Work station set up on site with a portable stereo-microscope.

2. Plan showing locations from which samples were collected



Plan of the church supplied by the client.



Enlargement of the previous image showing the prothesis and the north corridor.
 The green numbers refer to samples with the prefix PRO [prothesis]; the red ones indicate samples with the prefix CN [north corridor] (see the tables below).

3. Results of in situ observations and analyses

3.1 Perimeter walls of the church

3.1.1 Painted plaster on the internal walls of the church

Sample number	Area sample taken from	Brief microscopic description
E 1	North west wall, approximately 1.0 m to the left of the first ogival window, at a height similar to that of the base of the window itself. The sample included both the light-colored surface plaster and the underlying gray bedding mortar which is well-smoothed and pointed.	The fragment of mortar between the bricks (no. 1) is gray in color and composed of lime, fine, well-graded sand and charcoal finely dispersed in the binder. It may also contain scattered fragments of brick. The finishing plaster (no. 2) is light-colored with a well-smoothed and compacted surface. It is made up of lime, well-graded medium to fine sand and a few vegetable fibers, probably straw. Thickness 5.0 – 6.0 mm.
E 2	North west wall, to the left of the first ogival window, at the height of the arch of the window itself. The sample included both the light-colored surface plaster and the underlying gray bedding mortar which is well-smoothed and pointed.	The mortar and plaster are identical to those in sample E1. The thickness of the mortar varies between 5.0 and 7.0 mm.
E 3	North west wall, to the right of the second window from the right, at the height of the base. The sample included both the light-colored surface plaster and the underlying, well-smoothed, gray bedding mortar.	The sample collected is identical to the previous ones. The thickness of the plaster varies between 4.0 and 5.0 mm.
E 4	North west wall, inside the second window from the right: sample taken from about half-way up the right-hand impost. The sample included both the light-colored surface plaster and the underlying, well-smoothed, gray bedding mortar.	The mortar (no. 1) and the plaster (no. 2) are identical to those in the previous samples. In addition to straw, the plaster may also contain more valuable fibers (for example, cotton or linen). The thickness of the plaster varies between 4.0 and 8.0 mm.
E 5	North west wall, area between the doorway and the embrasure, at the same height as the embrasure. The sample was taken from a particular area of the wall, namely, between the stone	The bedding mortar between the bricks (no. 1) and the overlying plaster (no. 2) are identical in terms of structure and composition to those encountered in other samples.

Sample number	Area sample taken from	Brief microscopic description
	<p>arch of the doorway and the masonry. This structure of this part of the wall differs from that of the surrounding area.</p> <p>The sample included both the light-colored surface plaster and the underlying, well-smoothed and pointed, gray bedding mortar.</p>	<p>The thickness of the plaster varies between 5.0 and 7.0 mm.</p>
E 6	<p>North west wall, first niche from the left, right side of the impost of the arch at a height of approximately 2.5 m.</p> <p>The sample included the light-colored surface plaster, the underlying plaster covering the ogival portion of the niche and the bedding mortar between the bricks.</p>	<p>The mortar (no. 1) and the plaster covering the ogival section of the niche (no. 2) closely resemble each other. They are the same as the gray mortar described in the previous sample. Even the light-colored surface plaster (no. 3) is identical to the external plaster found in the previous samples. However, in this case, the plaster is particularly rich in straw. Furthermore, it is also relatively thick, varying between 13.0 and 17.0 mm.</p>
E 7	<p>North west wall, approximately 1.0 m to the left of the niche from which sample no. 6 was collected; the sample was taken at a height of approximately 5.0 m, a few centimeters lower than the first niche measuring at least 10 cm.</p> <p>The sample included both the light-colored surface plaster and the underlying, well-smoothed, gray bedding mortar.</p>	<p>The mortar (no. 1) and the plaster (no. 2) are identical to those in the previous samples. In this case there is a 'large' millimetric fragment of brick in the mortar. Furthermore, the plaster is relatively rich in straw. It varies between 5.0 mm and 7.0 mm in thickness.</p> <p>On top of the plaster we can also see: 3) a thin layer of red paint; 4) a thin blackish-brown layer that is probably an altered organic protective agent (for example, based on gum arabic).</p>
E 8	<p>North west wall, a few decimeters below sample no. 7. The sample included a small fragment of coarse brown brick present in pieces under the light-colored plaster covering the masonry. This is a repair effected during earlier restoration work.</p>	<p>The sample includes traces of the 'usual' light-colored plaster based on lime, fine sand and vegetable fibers and a layer of dark mortar made of silt and straw. The latter was applied during maintenance work to fill a gap in the underlying light-colored plaster.</p> <p>The restoration plaster is covered by a dark patina.</p>
E 9	<p>North west wall, first embrasure at the top from the left near the right side of the base.</p> <p>The sample included both the light-colored surface plaster and the underlying, well-smoothed, gray bedding mortar.</p>	<p>The fragment of mortar between the bricks (no. 1) is gray in color and made up of fine, well-graded sand and charcoal finely dispersed in the binder. It also contains a few fragments of brick.</p> <p>The finishing plaster (no. 2) is light in color and has a well-smoothed and compacted surface. It is made up of lime, well-graded medium-fine sand and abundant vegetable</p>

Sample number	Area sample taken from	Brief microscopic description
		fibers, probably straw. It is 5.0 – 6.0 mm thick.
E 10	North west wall, approximately 2.5 m from the corner with the south west wall, to the right of the blocked-up niche. The sample included both the light-colored surface plaster and the underlying, well-smoothed, gray bedding mortar.	The sample taken is identical to the previous one. The thickness of the plaster varies between 5.0 and 6.0 mm.
E 11	Back wall (south west), from one of the blue painted lines forming the circle of the great cross. The sample included a tiny millimetric flake from the edge of a whitish layer and the overlying paint layer.	The tiny flakes are made up of two layers: a thin, white, lime-based layer and a thin sky-blue layer comprising very fine-grained blue particles. Although precise identification of the pigment would require optical mineralogical analysis under a polarizing microscope, we can conjecture that this may be lapis lazuli.
E 12	Back wall (south west), on the same vertical as sample no. 11 to the right of the second embrasure up, at a height similar to that of the base. The sample included both the light-colored surface plaster and the underlying, well-smoothed, gray bedding mortar.	The fragment of mortar between the bricks (no. 1) is gray in color and is composed of lime, fine, well-graded sand, charcoal and occasional fragments of brick finely dispersed in the binder. The material is highly porous owing to the presence of minute globular cavities. It is thin in consistency. The finishing plaster (no. 2) is light in color with a well-smoothed surface. The plaster is composed of lime, medium-fine, well-graded sand and vegetable fibers (probably straw). The fibers are clearly visible on the surface as a result either of the compacting of the surface or of subsequent differential wear sustained by the plaster. It is 5.0 – 9.0 mm thick.
E 13 A	Back wall (south west), left side, a few decimeters below the small niche on the vertical external wall of the sacristy. The sample was taken to the right of the deep vertical lesion at a height similar to that of the base of the niche itself. The sample included the well-smoothed, gray bedding mortar, the light-colored surface plaster and thin layers of red and light yellow.	The fragment of mortar between the bricks (no. 1) is gray in color and is composed of lime, fine, well-graded sand, charcoal and occasional fragments of brick finely dispersed in the binder. The material is highly porous owing to the presence of minute globular cavities. It is thin in consistency. The finishing plaster (no. 2) is light in color with a well-smoothed and compacted surface. The plaster is composed of lime, medium-fine, well-graded sand and vegetable fibers. The fibers comprise straw and some cotton and linen. The more valuable fibers seem to be concentrated preferentially near the surface. The plaster is 5.0 – 6.0 mm thick.

Sample number	Area sample taken from	Brief microscopic description
		The plaster is overlaid by a further three layers: 3) thin whitish wash, submillimetric in thickness; 4) thin red layer, presumably based on hematite; 5) thin yellowish patina.
E 13 B	IAs above but to the left of the deep vertical lesion. The sample included the well-smoothed gray bedding mortar, the light-colored surface plaster and a thin layer of red.	The sample collected closely resembles the previous one. In addition to the gray bedding mortar (no. 1) and the overlying light-colored plaster (no. 2) made of lime, fine sand and straw (3.0 and 4.0 mm thick), the sample includes a whitish wash (no. 3) that is presumably lime-based and a thin red paint layer (no. 4).
E 14	Back wall (south west) almost at the corner with the south east wall, high up, below the cornice and the remains of the impost of a vault. The sample included both the light-colored surface plaster and the underlying, well-smoothed, gray bedding mortar.	The fragment of mortar between the bricks (no. 1) is gray in color and composed of lime, fine, well-graded sand, charcoal and occasional fragments of brick finely dispersed in the binder. The material is highly porous owing to the presence of minute globular cavities. It is thin in consistency. The finishing plaster (no. 2) is light in color with a well-smoothed and compacted surface. It is composed of lime, medium-fine, well-graded sand and vegetable fibers. The fibers comprise straw and some cotton and linen. The more valuable fibers seem to be concentrated preferentially near the surface. The plaster is 9.0 – 12.0 mm thick.
E 15	Back wall (south west) Almost at the corner with the south east wall, high up, from the cornice and the remains of the impost of a vault. The sample included the bedding mortar of the structure built of bricks positioned vertically.	The sample includes a fragment of dark-brown mortar based on silt and straw (no. 1) and a fragment of light-colored plaster (no. 2) made of lime, fine, well-graded, silicate-rich sand and abundant vegetable fibers. The plaster is 6.0 – 8.0 mm thick. The plaster is overlaid by a brown patina that may be concealing the paint layer or a finishing layer in general.
E 16	South east wall, corner with the south west wall, first embrasure up, from the base of the architrave. The sample included the light-colored finishing plaster.	The sample includes a thin fragment of light-colored finishing plaster composed of lime, medium-fine, well-graded sand and vegetable fibers, probably straw with some cotton and linen. The more valuable fibers seem to be concentrated preferentially near the surface. The plaster is less than 2.0 mm thick. The plaster is overlaid by a thin dark-brown patina.
E 17	Back wall (south west) from an area very close to where sample no. 14 was taken. The sample included both the well-smoothed, gray bedding mortar and the overlying	The fragment of mortar between the bricks (no. 1) is gray in color and is composed of lime, fine, well-graded sand, charcoal and occasional fragments of brick finely dispersed in the binder. The material is highly porous owing to the

Sample number	Area sample taken from	Brief microscopic description
	light-colored finishing plaster.	presence of minute globular cavities. It is thin in consistency. The finishing plaster (no. 2) is light in color with a well-smoothed and compacted surface. It is composed of lime, medium-fine, well-graded sand and vegetable fibers, probably straw with some cotton and linen. The more valuable fibers seem to be concentrated preferentially near the surface. The plaster is approximately 6.0 mm thick.
E 18	Back wall (south west) approximately 1.0 m from the corner with the south east wall. The sample was taken from the red basal strip, approximately 1.0 m thick, decorating the external wall around the cupola of the sacristy. The sample included both the light-colored surface plaster as well as the well-smoothed, gray bedding mortar.	The sample taken is identical to the preceding one with regard to mortar types: bedding mortar between the bricks (no. 1) and overlying plaster (no. 2). However, the latter does not seem to contain fibers other than straw. It is approximately 6.0 mm thick. The plaster is overlaid by a thin layer of red paint (no. 3), presumably based on hematite.
E 19	Back wall (south west), approximately 2.2 m up and taken from the gap in the plaster a few decimeters to the right of the Coptic inscription. The sample comprised the gray bedding mortar between the bricks with a well-smoothed and compacted surface.	The fragment of mortar is gray in color and is composed of lime, fine, well-graded sand, charcoal and occasional fragments of brick finely dispersed in the binder. The material is highly porous owing to the presence of minute globular cavities. Within it are occasional fragments of vegetable fiber and a few granules of calcareous rock (perhaps the remains of the original limestone that have not been entirely calcified). The material is thin in consistency.
E 20	North West Wall, approximately 1.3 m up, near the second niche to the left of the doorway. The sample comprised the gray bedding mortar between the bricks with a well-smoothed and	The structure and composition of the mortar was identical to that encountered in the previous sample. However, it did not contain vegetable fiber or calcareous rock fragments.

Sample number	Area sample taken from	Brief microscopic description
	compacted surface.	
E 21	North west wall, near the first niche from the right at a height of approximately 2.0 m, from within a gap in the plaster some 10 cm wide. The sample comprised the gray bedding mortar between the bricks with a well-smoothed and compacted surface.	The structure and composition of the mortar is identical to that encountered in sample E-19.

3.1.2 Doorway in the north west facade – finishing layers

Sample number	Area sample taken from	Brief microscopic description
E/PO – 1A	Internal doorway, architrave, left side. The sample comprises a small flake adhering to the stone, made up of a relatively thick white layer covered by a layer of red paint.	When examined under the stereo-microscope, the flake proved to be made up of the following layers: 1. thin, white, lime-based wash less than 1 mm thick, possibly incorporating occasional fragments of calcareous rock; 2. red paint layer, presumably based on hematite; 3. thin yellowish layer (patina produced by alteration).
E/PO – 1B	A few centimeters below the previous sample. The sample comprises a small flake adhering to the stone, identical to the one taken in sample no. 1 and a fragment of the overlying light-colored plaster containing vegetable fibers.	Study of the two flakes comprising the sample, plus the information acquired whilst collecting the samples have enabled us to reconstruct the stratigraphy present in situ. In particular, starting from the innermost layer, the following are visible: 1) plaster made of fine, well-graded, silicate-rich sand and lime; 2) intermittent lime-based wash; 3) red paint layer based on hematite; 4) thin yellowish layer (patina produced by alteration); 5) Restoration finishing plaster based on lime, well-graded, silicate-rich sand and vegetable fibers (plaster identical to that covering the internal walls of the church).
E/PO – 1C	The sample, taken from above the previous one, comprised a small flake made up of a white wash and a thin blue layer.	The flake is made up of the following layers, starting with the innermost: 1) traces of plaster composed of lime, fine, silicate-rich sand and vegetable fibers; 2) lime-based wash; 3) thin paint layer, probably blue in color and pigmented with lapis lazuli (the presence of a yellowish patina makes it difficult to study the paint layer with a stereo-microscope alone).
E/PO – 2	Architrave within decorated frieze at the height of the left upright. Several small flakes were collected, ranging from millimetric to submillimetric in size and comprising a white layer and a dark blue surface paint layer.	Study of the various flakes comprising the sample, plus the information acquired whilst collecting the samples have enabled us to reconstruct the stratigraphy described below. 1) calcareous stone; 2) thin, lime-based wash; 3) red, hematite-based paint layer; 4) thin, lime-based wash;

Sample number	Area sample taken from	Brief microscopic description
		5) red and yellow background paint layer; 6) thin, blackish level possibly produced by the alteration of the red pigment; 7) thick, lime-based wash; 8) blackish layer possibly caused by deposition of particulate matter containing carbon (lamp black).
E/PO – 3	A few decimeters below the preceding sample, from the surface of the architrave; sample taken from a small lobe of plaster overlying several finishing layers (white washes and green paint layers). The sample comprised both the surface plaster and the underlying layers.	Study of the various flakes comprising the sample, plus the information acquired whilst collecting the samples have enabled us to reconstruct the stratigraphy described below. 1) relatively thick, lime-based layer containing little sand, brick dust and occasional fibers; 2) thin, lime-based wash; 3) red and yellow paint layer; 4) thin, lime-based wash; 5) green paint layer, probably wax-based; 6) thin black layer, based on lamp black.
E/PO – 4	Architrave, right side at the height of the upright in an area where several overlying finishing layers have been observed, including some red and green layers. The sample included all the layers.	The flake in the sample was made up of the following layers, starting from the innermost: 1) lime-based wash; 2) red paint layer, presumably hematite-based; 3) lime-based wash; 4) red paint layer, presumably hematite-based; 5) lime-based wash; 6) thin black layer composed of very fine grains, presumably based on lamp black.

3.1.3 External walls (south east and south west sides)

Sample number	Area sample taken from	Brief microscopic description
1 SE/SW	South east side, near the corner with the south west side within the large cavity (over 1 m) caused by the partial fall of bricks from the wall. The sample, taken from a height of approximately 4.5 m, included the bedding mortar between the bricks.	The sample comprises a fragment of grayish mortar made with lime, fine, well-graded sand, lamp black and fragments of brick finely dispersed in the binder. The material is highly porous owing to the presence of minute globular cavities. The mortar contains a single vegetable fiber. The material is thin in consistency.
2 SE/SW	South east side, near corner with south west side, from the arch of the blocked-up window. The sample, taken from the left side of the arch, included the bedding mortar between the bricks.	The sample comprises a fragment of grayish mortar made with plenty of lime, fine, well-graded sand, lamp black and fragments of brick finely dispersed in the binder. The material is highly porous owing to the presence of minute globular cavities. The mortar contains occasional vegetable fibers. It is thin in consistency.
3 SE/SW	South east side at the corner with the south west side, from the pointing of one of the corner stones.	The sample comprises a fragment of grayish mortar made with plenty of lime, fine, well-graded sand, lamp black and fragments of brick finely dispersed in the binder. The mortar contains occasional vegetable fibers. It is thin in consistency.
4 SW/SE	South west side, near the corner with the south east side, first window down, from the inside of the key of the vault of the ogive. The sample comprised the plaster adhering firmly to the mortar between the bricks.	The sample comprises a fragment of grayish mortar made with plenty of lime, fine, well-graded sand and fragments of brick finely dispersed in the binder. The mortar contains very occasional vegetable fibers. It is thin in consistency. The mortar does <u>not</u> contain charcoal.
5 SW/SE	South west side, near the corner with the south east side, first window down, from the external part of the arch, right side. The sample comprised the external pointing of the bricks.	The sample comprises a fragment of grayish mortar made with plenty of lime, fine, well-graded sand, lamp black and fragments of brick finely dispersed in the binder. The mortar contains very occasional vegetable fibers. It is thin in consistency.
6 SW/SE	South west side, near the	The sample comprises a fragment of grayish

Sample number	Area sample taken from	Brief microscopic description
	corner with the south east side, first window down, from the central portion. The sample comprised the bedding mortar between the bricks.	mortar made with plenty of lime, fine, well-graded sand, lamp black and fragments of brick finely dispersed in the binder. The mortar contains very occasional vegetable fibers and a few lime crumbs. It is thin in consistency.

3.2 Interior of the church

3.2.1 *Facade*

Sample number	Area sample taken from	Brief microscopic description
ICO-1	Facade, left side, from about two thirds of the way up the first pilaster, from the area above a red band, near the edge of a gap. In this area, the plaster is light in color with a well-smoothed and compacted surface. The sample included almost the entire thickness of the plaster.	The sample collected comprised a light-colored plaster made up of lime, well-graded, medium-fine sand and occasional vegetable fibers (its thickness varies between 4.0 and 5.0 mm).
ICO-2	Facade, left side, at the outer edge of the original masonry, near a gap that skirts the upper arm of the large circular cross. The sample comprised several flakes, ranging from millimetric to submillimetric in size, of the white plaster on which the cross is painted.	The plaster sampled has the same composition and texture as the previous type (sample ICO-1).
ICO-3	Facade, left side, second tier, arch, right side near the impost, from a blue geometric decoration. The sample comprised several submillimetric flakes of plaster with a blue paint layer.	A comparative examination of the flakes in the sample has enabled us to reconstruct the following stratigraphic sequence, starting with the innermost layer. 1) pink paint layer, probably resulting from the application of red lacquer in a wax medium (paint layer associated with the third phase of painting or a slightly older phase); 2) thick, white, lime-based wash; 3) thin blue paint layer, containing very fine

Sample number	Area sample taken from	Brief microscopic description
		blue particles. Although a precise identification of the pigment would require optical mineralogical analysis with a polarizing microscope, we can speculate that this may be lapis lazuli.
ICO-4	Facade, left pilaster strip above the area giving access to the north conch, from the edge of the gap in the plaster near the fluted column (phase datable to 12th century). The sample comprised a millimetric flake of plaster with the overlying paint layer.	The flake was taken from a white plaster based on lime and abundant vegetable fibers, distinguished by its well-smoothed surface. It seems that the mix does not contain sand.
ICO-5	Facade, right pilaster strip over the area giving access to the north conch, from the edge of a lobe of plaster datable to the 12th century and depicting the face of a saint. The sample comprised a millimetric flake of plaster with the overlying paint layer.	The sample is identical to the preceding one (ICO-4).

3.2.2 North west wall, area surrounding the painting of the medieval knight on horseback

Sample number	Area sample taken from	Brief microscopic description
CAV-1	North west wall, approximately 60 cm from the facade, from the edge of a gap in the plaster at least 10 cm wide. The sample included both the gray bedding mortar from between the bricks and the overlying light-colored plaster.	The fragment of gray mortar (no. 1) proved to be made up of carbonized lime, fine, silicate-rich sand, charcoal, brick powder and occasional vegetable fibers. The overlying light-colored plaster (no. 2) proved to be made up of lime, well-graded, medium-fine sand and abundant vegetable fibers.
CAV-2	North West Wall, from the area of masonry below the embrasure; sample taken from the edge of the gap in the plaster. The sample only	The gray mortar is identical to that collected in the previous sample.

	included the gray bedding mortar from between the bricks. In this area, the mortar is well-smoothed and pointed.	
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3.2.3 Prothesis – North corridor

Sample number	Area sample taken from	Brief microscopic description
CN-A	North corridor, north west wall, area in front of the test wedge opened to the right of the niche, near the gap, at a height of approximately 1.7 m. The sample included the entire thickness of the plaster.	Examination of the flake in the sample has enabled us to reconstruct the following stratigraphic sequence, starting with the innermost layer. <ol style="list-style-type: none"> 1. light-colored plaster made up of lime, well-graded, medium-fine sand and occasional vegetable fibers. 2. gray layer probably colored with lamp black; 3. thin, light-colored layer.
CN-B	North corridor, south east wall, at the base of the test wedge that brought to light the decoration featuring polychrome circles. The sample, taken from a height of approximately 1.7 m, comprised the entire thickness of the whitish plaster overlying the phase with the circular decoration.	Examination of the fragment in the sample has enabled us to reconstruct the following stratigraphic sequence, starting with the innermost layer. <ol style="list-style-type: none"> 1. light-colored plaster made up of lime, well-graded, medium-fine sand and occasional vegetable fibers; 2. thick, lime-based wash, very well-smoothed, that has turned gray on the surface.
CN-C1	North corridor, north west wall, corner with the north east wall, from the edge of a gap at least 10 cm wide, at a height of approximately 1.1 m.	The surface fragment (C1) comprises: <ol style="list-style-type: none"> 1. light-colored plaster made up of lime, well-graded, medium-fine sand and occasional vegetable fibers (surface well-smoothed); 2. thin blackish deposit made up of particulate matter.
CN-C2	Two samples were taken in sequence. the first (C1) comprised the entire thickness of the surface plaster; the second (C2) comprised the underlying mortar with a well-smoothed surface. The two layers of mortar are partially separated by a break.	The sample comprises a fragment of grayish mortar made with lime, plenty of fine, well-graded sand, charcoal and occasional fragments of brick finely dispersed in the binder. The mortar has a high aggregate: binder ratio and is distinguished by a well-smoothed and compacted surface caused by immediate working.

Sample number	Area sample taken from	Brief microscopic description
CN-D	North corridor, south east wall, from the test wedge opened on the side of the small vault. The sample comprised the entire thickness of the plaster covering the brick masonry.	<p>Examination of the fragment in the sample has enabled us to reconstruct the following stratigraphic sequence, starting with the innermost layer.</p> <ol style="list-style-type: none"> 1. light-colored plaster made up of lime, well-graded, medium-fine sand and abundant vegetable fibers; 2. traces of a gray layer probably produced by the presence of a carbon-based pigment; 3. traces of a whitish layer, probably lime-based.
CN-E	Prothesis, south west wall, to the right of the access door to the church at a height of approximately 1.2 m. The sample comprised a fragment of very well-smoothed, gray plaster.	<p>The sample comprises a fragment of grayish mortar made with lime, fine, well-graded sand, abundant charcoal and occasional fragments of brick finely dispersed in the binder. Some of the fragments of charcoal still retain the original cellular structure of the wood they were made from.</p> <p>The mortar is distinguished by a well-smoothed surface.</p>
CN-G1	Prothesis, north east wall, niche, right impost.	Sample G1 comprises a fragment of light-colored plaster made up of lime, well-graded, medium-fine sand and relatively abundant vegetable fibers;
CN-G2	Two samples were taken in sequence. The first (G1) comprised the entire thickness of the surface plaster; the second (G2) comprised the underlying mortar with a well-smoothed surface. The latter was adhering very firmly to the brick masonry.	Sample G2 comprises a fragment of grayish mortar made with lime, fine, well-graded sand, charcoal and occasional fragments of brick finely dispersed in the binder. The mortar is distinguished by a well-smoothed surface produced by compacting with an appropriate tool.
CN-H1	Prothesis, north east wall to the right of the niche, at the top, from the edge of a gap at least 10 cm wide, repaired with a mud and straw mortar.	Sample H1 comprises a fragment of light-colored plaster made up of lime, well-graded, medium-fine sand and vegetable fibers.
CN-H2	Two samples were taken in sequence. The first (H1) comprised the entire thickness of the whitish surface plaster; the second (H2) comprised the underlying gray mortar with a	Sample H2 comprises a fragment of grayish mortar made with lime, fine, well-graded sand, charcoal and possibly, occasional fragments of brick finely dispersed in the binder. The mortar has a high aggregate: binder ratio and is distinguished by a well-

Sample number	Area sample taken from	Brief microscopic description
	well-smoothed surface.	smoothed surface produced by compacting with an appropriate tool.
PRO-1	Prothesis, niche, left side, base of the ogival arch. Bedding mortar from between the bricks taken from a depth of a few centimeters.	The sample comprises a fragment of grayish mortar made with lime, fine, well-graded sand, charcoal finely dispersed in the binder and occasional vegetable fibers.
PRO-2	<p>Prothesis, south west wall, to the right of the access door to the church at a height of approximately 1.2 m, from the 10 cm test hole opened in the masonry.</p> <p>The sample comprised: a fragment of very well-smoothed gray plaster (Pro-2INT) and the underlying structural bedding mortar from between the bricks (Pro-2 sup and Pro-2 malta) very similar to the plaster. The bedding mortar is represented by two fragments taken from different depths inside the test hole.</p>	<p>A comparative study of the three fragments taken in sequence from the sampling area has enabled us to reconstruct the following stratigraphic sequence:</p> <p>1) bedding mortar from the masonry made up of lime, well-graded fine sand, charcoal finely dispersed in the binder and vegetable fibers. The mix is distinguished by spherical pores diffused throughout its mass; it has fair cohesive qualities;</p> <p>2) plaster identical to the underlying mortar.</p> <p>Between the two layers and in the larger cavities within the two layers, minute aggregates of very fine, acicular, colorless, translucent crystals can be seen. These are salts that have crystallized inside the pores of the material (sub-efflorescence).</p>
PRO-3	<p>Prothesis, niche, back wall, from a height slightly above the architrave.</p> <p>The sample comprised several fragments of gray mortar in direct contact with the brick wall. The sample was taken once the mud mortar applied during earlier restoration work had been removed.</p>	The gray mortar contained in the sample is identical to those described above (see for example, sample PRO-2).
PRO-4	Prothesis, niche, left side, in the area with a 'mark', probably the housing of a panel used as an architrave. The sample comprised	All the sample fragments all proved to be of a grayish mortar made with lime, fine, well-graded sand, charcoal and occasional fragments of brick finely

Sample number	Area sample taken from	Brief microscopic description
	several fragments of gray bedding mortar from the brick masonry.	dispersed in the binder. There were also very occasional vegetable fibers within the binder (straw).
PRO-5	Prothesis, niche, a few decimeters to the right of the previous sample, from the area with a 'mark', probably the housing of a panel installed as an architrave. The sample comprised several fragments of gray bedding mortar from the brick masonry.	Gray mortar identical to the preceding sample.
PRO-6	Prothesis, niche, from the projecting top of the ogival arch.	The sample comprises a fragment of grayish mortar made with lime, fine, well-graded sand and charcoal finely dispersed in the binder. Within the mix there are possibly occasional fragments of brick and a few granules of calcareous rock (perhaps the remains of the original limestone that have not been entirely calcified?).
PRO-7	Prothesis, South west wall bearing the painting of the Madonna and Saint, impost of the vault, from the corner with the large gap in the plaster. Bedding mortar from the bricks of the vault.	Dark-brown mortar made of silt and fairly coarse vegetable fibers, probably straw.
PRO-15 (*)	Prothesis, south west wall bearing the painting of the Madonna and Saint, right side, from the gap in the plaster near the red cross. In the sampling area, three plaster types overlying the masonry can be distinguished. As a result of the stratigraphic information collected in situ, the first plaster type can be associated with the first or second phase of construction of the church; the second layer can be attributed to the third phase, whilst the outermost, light-colored plaster is associated with the 10th-13th century phase. The sample comprised a fragment including the only plaster associated with the presumed third	The fragment of plaster in the sample (thickness varying between 4.0 and 4.5 mm) is in turn comprised of two layers applied in rapid succession. The innermost comprises lime, well-graded medium sand and occasional vegetable fibers; the other layer however comprises a white mortar made of slaked lime and powdered calcareous rock (alabastrine limestone). The latter layer has been very well smoothed and compacted.

Sample number	Area sample taken from	Brief microscopic description
	phase (the sample comprises the entire thickness of the plaster).	
(*) Samples PRO-8 to PRO-14 were not analyzed during this phase of work.		

4. Closing comments

The processing, interpretation and comparison of the results obtained from in situ observations and stereo-microscopic analyses have enabled us to formulate the comments set out in brief below.

The structural mortars used in the perimeter walls of the church, both internally and externally, closely resemble each other in terms of color, texture and composition⁽¹⁾. They constitute a mix obtained by combining slaked lime, fine, silicate-rich sand with a uniform grain size, charcoal and thin brick powder dispersed in the binder.

Several samples also contain occasional vegetable fibers (probably straw), while all are distinctly porous, mainly with bubble-shaped pores. The surface cohesion of this kind of mortar, empirically assessed, is in general fair, or not very high.

The minor variations observed between the samples are not such as to allow this kind of mortar to be separated into two or more groups. The absence of fibers or the different concentrations of the other components can be justified quite easily by the naturally heterogenous nature of the material and the relatively diminutive proportions of the samples collected.

A considerable degree of homogeneity was also encountered with regard to application. In the various areas of masonry investigated, the bedding mortar had been smoothed and compacted with an appropriate tool, and the excess had been spread on the surface of the adjacent bricks.

In the *prothesis*, even the innermost plaster types, in direct contact with the brick masonry, proved to share the same composition as the underlying bedding mortar between the bricks. The same is also true of all the mortar types within the open niche in the north east wall of the *prothesis*. Therefore, the oldest mortar and plaster types in this area can be classified using the same definition used above for the perimeter walls of the church.

Therefore, from the point of view of the nature of the mortar types, we have no proof or benchmarks to indicate the different ages of the masonry examined. Only one sample (1 SW/SE), taken from the external facade (south west side, near the corner with the south east side, from the inside of the key of the vault of the ogive of the first window down), proves an exception to this rule. The sample, comprising plaster adhering strongly to the masonry, differs from the others in that the mix does not seem to contain charcoal.

The internal perimeter walls of the church are finished with a single layer of plaster decorated with crosses that therefore can be attributed to a single period of work. The numerous samples taken at various heights on the north west, south west and south east walls are similar in terms of texture, composition and working. In all cases the light-colored plaster proves to be made up of a mortar of lime, fine sand and vegetable fibers; the sand has fairly uniform medium to fine grains and is rich in silicates. The vegetable fibers are mostly straw; in some cases it appears that more valuable fibers such as cotton and linen have been used.

¹ Bedding mortar from between the courses of brick in the masonry was taken from the *prothesis*, the north corridor, the internal walls (north west, south west and south east) and the external walls (south west/south east walls).

With regard to the dating of the plaster, one indication exists in the form of the possible presence of lapis lazuli in one of the crosses on the back wall. The paint layer, which is contemporaneous with the plaster, seems to have been colored with this pigment that gradually replaced Egyptian Blue in blue backgrounds. If confirmed by specific analyses, the presence of lapis lazuli would represent a valid piece of evidence in support of the hypothesis, formulated on the basis of historical and architectural data, which attributes the plaster to the 10th-13th centuries.

This means that the white plaster on which the knight on horseback and the crosses on the facade are painted and the external plaster in the north corridor and the prothesis can also be associated with this same period. The analyses carried out have indicated substantial uniformity of both texture and composition.

On the other hand, the plaster of the lobes with the saints' faces visible in the facade is slightly different in nature. In this case it seems that the plaster on which the paintings were executed was made with lime and vegetable fibers alone (the mortar does not contain sand therefore). Should this be confirmed by the results of more in-depth analysis (study of thin section using an optical microscope under reflected light, or better still, petrographical mineralogical analysis of thin section using a polarizing microscope), we could conjecture the existence of different decorative phases within the period between the 10th and 13th centuries.

In the prothesis and the north corridor, certain information indicates that the paintings of the braids, peacocks, eagles etc. can be associated with the first phase of decoration of the church.

The presence of a well-smoothed white stucco closely resembling that used for the surfaces of the first tier of the triconch, now associated with the third phase of decoration⁽²⁾, has been identified on top of the plaster on which these paintings were executed. The samples analyzed during the course of the previous missions actually had indicated that the presence of two different plaster types was a distinctive feature of the third phase of painting. The plaster used in the first tier is a clear white color, comprising a mortar of lime and calcareous stone powder (alabastrine limestone) with a well compacted surface flattened in a possible imitation of marble.

On the other hand, the plaster used in the upper tiers was made of a mortar of lime and alluvial sand.

The doorway in the north west side differs clearly from the adjacent walls with regard to the number and type of finishing layers covering it. Although the investigative methods used make it difficult to reconstruct the complete sequence of layers on the surface of the doorway, we can state that the plaster, wash and paint layer associated with the third phase of decoration are present on the doorway. The presence of a green, wax-based paint layer actually confirms this association.

² See the reports by Artelab s.r.l. produced after the previous missions and the information obtained from the examination of sample PRO-15, taken on this occasion.

Furthermore, in sample E/PO-3, under the layers associated with the third phase there are others that can be associated with the second or first phase of work (compare with earlier reports by Artelab s.r.l.). In particular, the entire stratigraphic sequence encountered in the E/PO-3 sampling area is as follows: 1) relatively thick layer based on lime, a little sand, brick powder and a few fibers; 2) thin lime-based wash; 3) red and yellow paint layer; 4) thin lime-based wash; 5) green paint layer, probably wax-based; 6) thin black layer based on lamp black. Layers nos. 1 to 3 can be associated with the first phase whilst the rest can be associated with the third phase.

In sample E/PO – 1B, a plaster composed of lime, fine sand and straw, closely resembling that applied to the internal perimeter walls of the church (phase of the crosses: 10th – 13th centuries) was encountered on top of the presumed third phase layers.

The investigations have highlighted a peculiarity of the construction of the vaults that probably follows from the period of their construction. The bedding mortar between the bricks differs from that of the masonry beneath the vault. Whilst the latter, as stated above, is consistently composed of a mortar of lime, fine sand, brick powder and charcoal, the bedding mortars of the vaults are made of silt and straw. This composition has been verified both inside the *prothesis*, in the north corridor and in the back wall of the nave at the corner with the south east wall.

The information acquired as a result of the present study has enabled us to establish the points set out briefly below.

1. Masonry structures

Two different types of mortar were used to construct the *vertical walls* and the *vaults*. For the *vertical walls*: mortar based on slaked lime, fine, well-graded, silicate-rich sand, charcoal and soft brick powder dispersed in the binder. For the *vaults*: silt and straw. However, no difference in the materials used to construct the masonry nucleus between the *prothesis*, the north corridor and the nave has been observed.

2. Plaster and polychrome

2.1 Nave

2.1.1 *Perimeter walls, internal and external surfaces*

All the plaster covering the walls of the nave has the same composition and structure, having been produced using the same materials and working methods. This plaster is made of lime, fine sand and vegetable fibers that associate it, on the basis of art historical, architectural, stratigraphic and compositional data, to the period of the 10th to 13th centuries. The probable presence of lapis lazuli in the blue background to the crosses further confirms this dating.

2.1.2 *Stone doorway*

The stone elements of the doorway that are visible beneath a plaster identical to that applied to the walls of the nave (10th-13th centuries) however have paint layers

that can be associated with two of the earlier phases found in the triconch. In particular, these are paintings of the third phase (with wax finishing) and, probably, the first phase.

2.2 North West Wall, area with the painting of the medieval knight on horseback

A light-colored plaster with polychrome decoration very similar to that covering the internal walls of the nave has been applied to the supporting masonry.

2.3 Facade

The plaster supporting the paintings of the saints' faces shows analogies with the plaster on the walls of the nave associated with the 10th – 13th centuries. They are composed of whitish mortar, based on lime and vegetable fibers. The absence of sand in the mix, if confirmed by laboratory analyses, could confirm the hypothesis formulated on the basis of stylistic features, according to which the paintings were done at a later date (for example, 12th-13th centuries) than the paintings in the nave.

It is not superfluous to stress that the plaster bearing the paintings with the saints' faces was applied over late antique paintings executed on mortar macroscopically similar to that encountered in the triconch. The layers between the stone support and the late medieval plaster with the saints are actually similar to those in the triconch.

2.4 Prothesis - north corridor in relation to the triconch

The following layers have been observed over the brick masonry characterized by the same bedding mortar as used in the nave:

1. a white, well-smoothed plaster based on lime and powdered alabastrine limestone, identical to that in the first order of the triconch, associated to date with the third phase of work (late antique phase);
2. a light-colored plaster based on lime, fine sand and vegetable fibers closely resembling the medieval plaster in the nave associated with the 10th-13th centuries.

The information in this paragraph derives from the processing of results obtained from close observation of the surfaces, the opening of test wedges and preliminary analyses under the stereo-microscope, carried out in situ. More in-depth information capable of confirming the data acquired or of supplementing or amplifying our knowledge about the materials and decorative phases of the church can be obtained by subjecting some of the more representative samples to laboratory analysis.

In particular, it would be desirable to explore in greater detail the points set out below.

1. Identify with certainty the blue pigment, judged at a rough guess to be lapis lazuli, used in the blue background of the crosses in the nave and in some polychrome geometric decorations in the facade.
2. Study the plaster types in greater depth in order to acquire information leading both to the definition of further phases of work and to the correlation of paintings executed in different areas of the church. In particular:
 - 2.1 study the plaster bearing the paintings of saints' faces, comparing it with the plaster on the walls of the nave;
 - 2.2 analyze the plaster samples taken from the north corridor (area with circular decorations) and the *prothesis* (paintings of peacocks and eagles) and compare them with plaster from the first and second phases of painting in the triconch;

- 2.3 compare the plaster of the three oldest phases in the triconch with the oldest plaster identified in the *prothesis* and the north corridor.
3. Identify the binder of the paint layer with the circular geometric decorations in the north corridor.

Appendix

Images showing locations from which samples were taken

3.1 Church perimeter walls

3.1.1 *Painted plaster on the interior walls of the church*



Sample E-1.



Sample E-2.



Sample E-3.



Sample E-4.



Sample E-5.



Sample E-6.



Sample E-7.



Sample E-8.



Sample E-9.



Sample E-10.



Sample E-11.



Sample E-12.



Samples E-13A and E-13B.



Sample E-14.



Sample E-15.



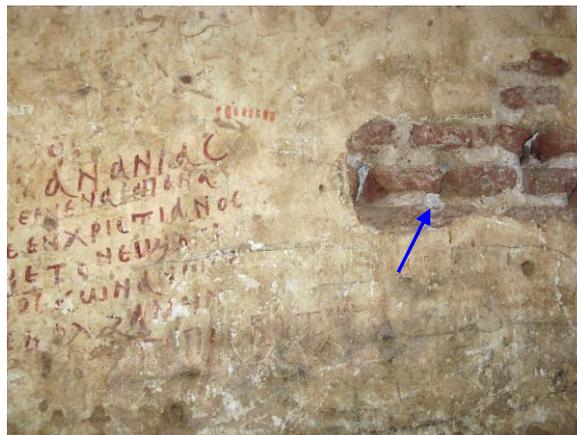
Sample E-16.



Sample E-17.



Sample E-18.



Sample E-19.



Sample E-20.



Sample E-21.

3.1.2 Doorway in the north west facade – finishing layers



Samples E-PO – 1A, 1B and 1C.



Sample E-PO – 2.



Sample E-PO – 3.



Sample E-PO – 4.

3.1.3 External walls (south east and south west sides)



Sample SE/SW – 1.



Sample SE/SW – 2.



Sample SE/SW – 3.



Sample SW/SE – 4.



Sample SW/SE – 5.



Sample SW/SE – 6.

3.2 Interior of the church

3.2.1 *Facade*



ICO - 1.



ICO - 2.



ICO - 3.



ICO - 4.



ICO - 5.

3.2.2 North west wall, area surrounding the painting of the medieval knight on horseback



CAV - 1.

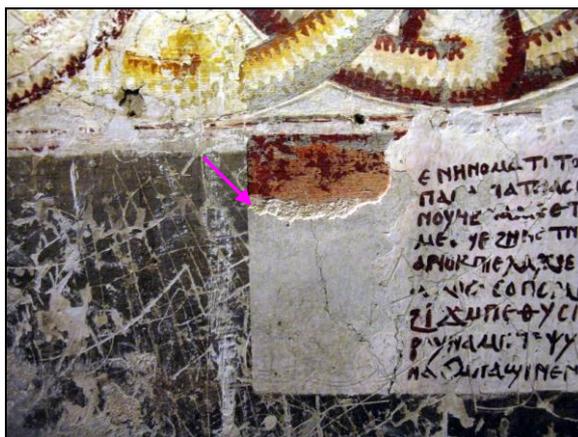


CAV - 2.

3.2.3 Prothesis – North Corridor



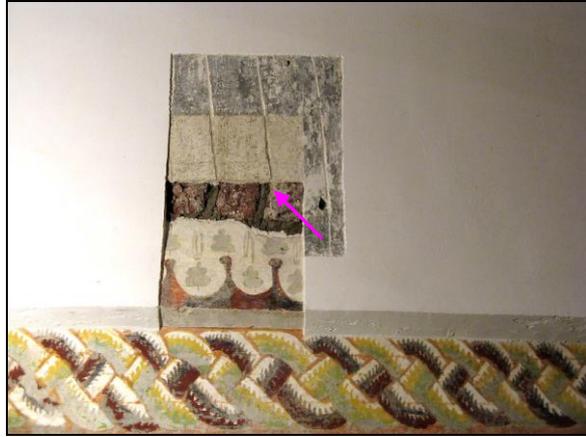
CN-A.



CN-B.



CN-C.



CN-D.



CN-E.



CN-G.



CN-H.



PRO-6.



PRO-7.



PRO-15.