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Geological and mineralogical investigation. PAVA project. Italy. Part I.

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Introduction

Geological, mineralogical and other investigations of site near San Jan de Asso were performed (realization of PAVA project) during 28.06-16.07 2008. The site contains, at the base, the rests of destroyed byzantine church (B.CH. - photo 0) and it's been explored for more than eight years by a group of archaeologist directed by prof. S. Campana (Campana 2005, 2008 a, b, Campana et al 2006, 2007, 200A). Early medieval church- E.M.CH. was built on the walls of this monument. This church was, once again, destroyed and early medieval church was built over the rests, next to the medieval church – M.CH. (Campana et al The Vall d'Asso project. The first eight years of work - draft copy).

Photo 0. General picture of the site (from West)

The aim of presented investigation (part I) was to determine geological layers and relation between theses layers and phases of functioning of the site. On the other hand documentation of the rests of byzantine church as well as reconstruction of the elements of temple was performed.

Geology and mineralogy of sediments

Determination of geology as well as mineralogy of sediments present under the temple and deposited during functioning of churches was performed for understanding of technical parameters of sediments on which the byzantine church was constructed. On the other hand the understanding of sequence of geo-archaeological layers helps determine sequence of tombs present around the churches i.e. and also relations between phases of functioning of churches and phases of cemetery. Because of all supposition the profiles of sediments were examined at places marked on fig 1.

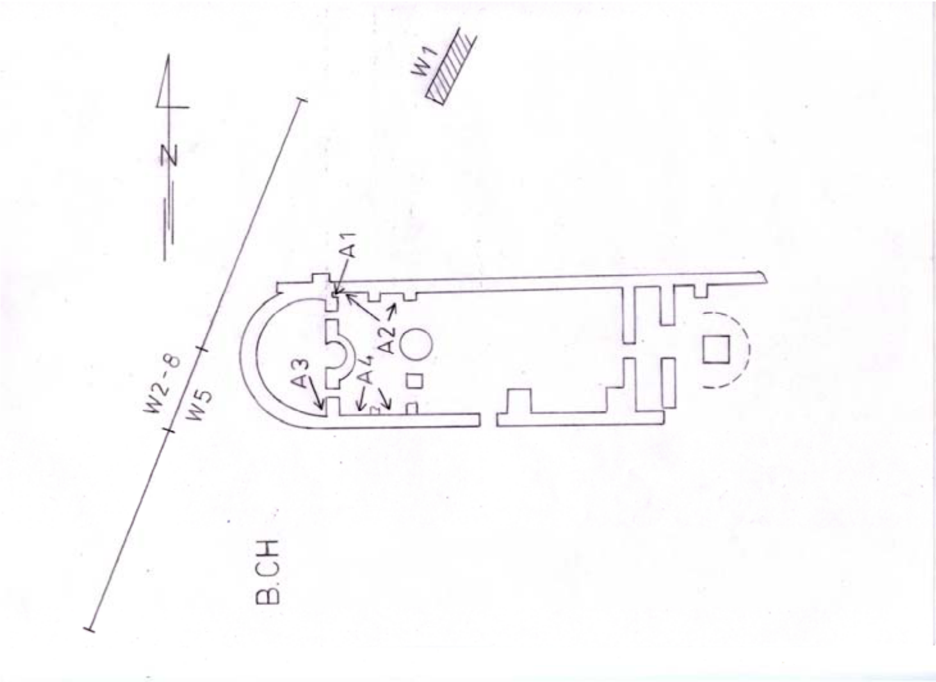

Fig. 1 Rests of byzantine church - (B.CH)
W1 – location of geological profile W1 (Fig. 2), W2-8 – location of West geological profile where W5 is part of profile (with tombs), A1-A4 places of investigation and reconstruction of fragments of byzantine church

Analyses of profile W-1 (Fig. 2) help select six layers (1-6) where the lowest layer (6) represent natural grayish clayey mudstone. Over this sediments one can see the sequence of geo-archaeological layers (5-1) represented by grayish and beige-grayish muds containing various admixture of anthropogenic admixture represented mostly by fragments of bricks. Some of layers contain mentioned admixture in all volume of sediments. This suggest that they are the sediments deposited during construction of church. At other layers fragments of bricks are present mostly at the irregular top of layers. This means that they are (rests of bricks) concentrated on natural surface washed out by rains.

Analyses of profile W5 (part of profile W2-8) showed evident relation between geo-archaeological layers and the presence of tombs at the profile of sediments (Fig. 2). On the base of geological sequence one can see younger and older tombs around the church. Older tombs are located deeper at archaeological profile while younger are present more shallow.

Observed geological situation suggests that tombs present at layers 4-5 comes from byzantine phase of functioning of the site while tombs present at layers no 2-3 are from early medieval phase. Tombs present at layers 0-1 are the youngest i.e. slightly later medieval.

Performed geological investigation may help to determine the age of tombs and the relation between tombs and phases of functioning of churches. Sometimes the separation of layers is impossible especially when they are very thin.

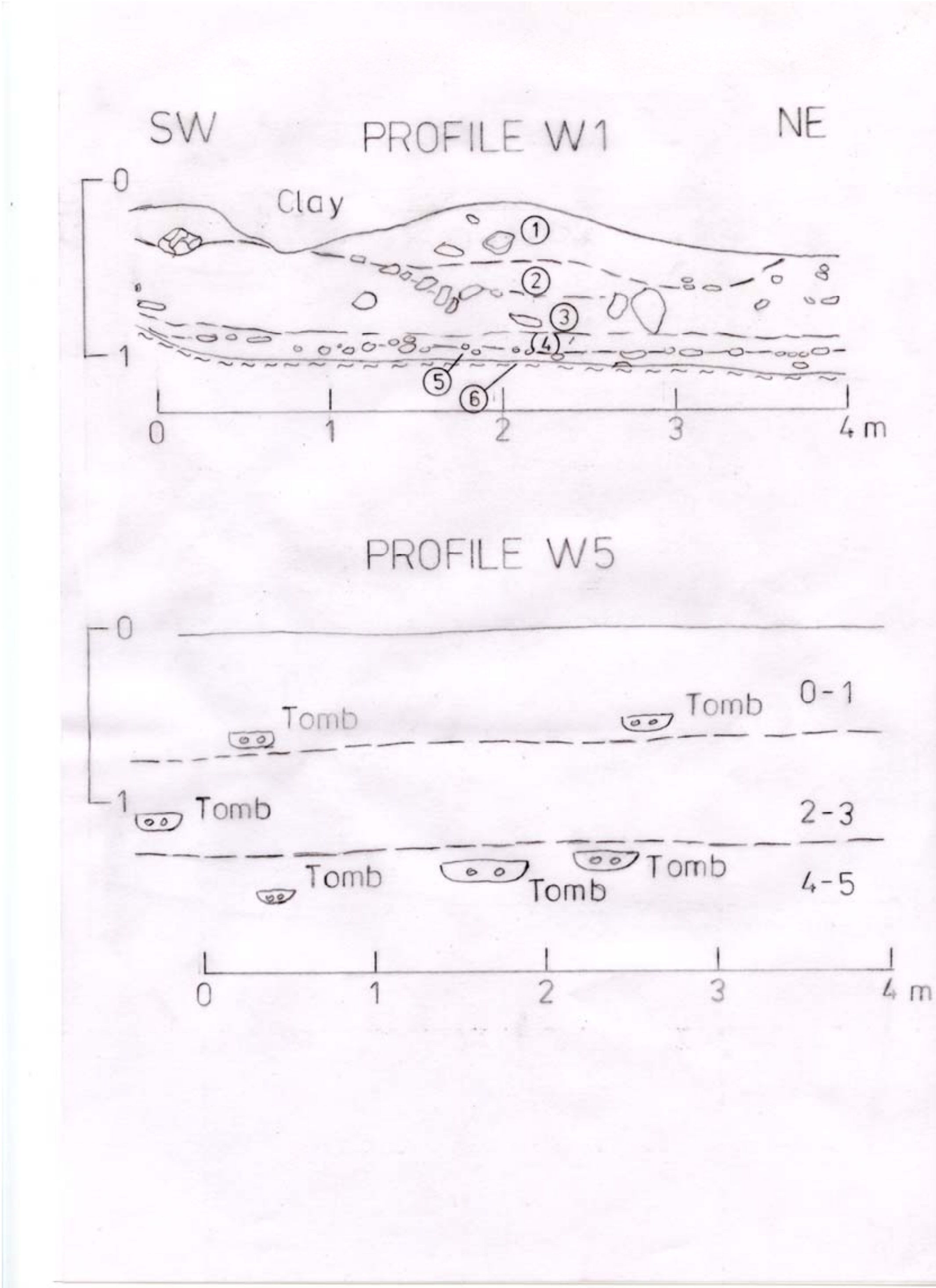

Fig. 2 Profile W1- 1-6 geo-archaeological layers, layer no 6 represents natural sediment. Profile W5 - part of geo-archaeological profile W2-8 where one can see the relation between position of tombs (at the profile of sediments) and sequence of layers (no 0-1 up to 4-5)

Mineralogy of geo-archaeological layers no 6-3

Examinations of samples representing geoarchaeological layers were performed using polarizing light microscopy and X-ray diffractometry (Dron 2,5 diffractometer).

Microscopic observation confirmed that all layers are composed of clay minerals quartz, micas and traces of plagioclases as well as K-feldspars (Photo 1A-1D, Table 1)

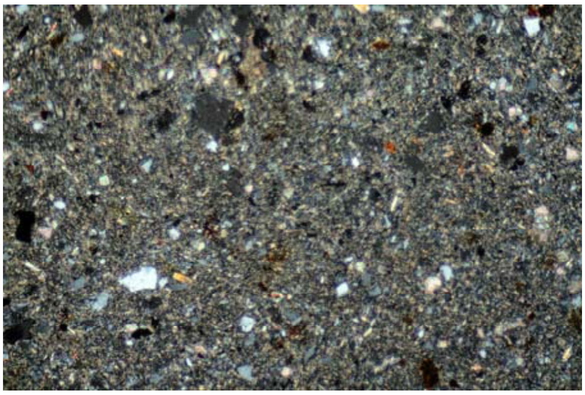

Photo 1A Structure of natural sediment (6) present under B.CH. Polarizing light microscope, polaroides X, magnification 40 x

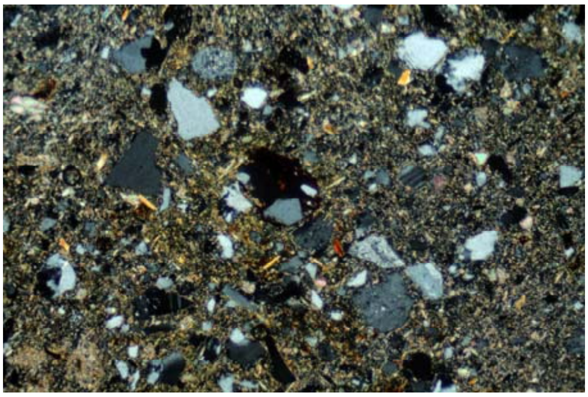

Photo 1B Structure of layer 5 (see Fig. 2) Polarizing light microscope, polaroides X magnification 40 x

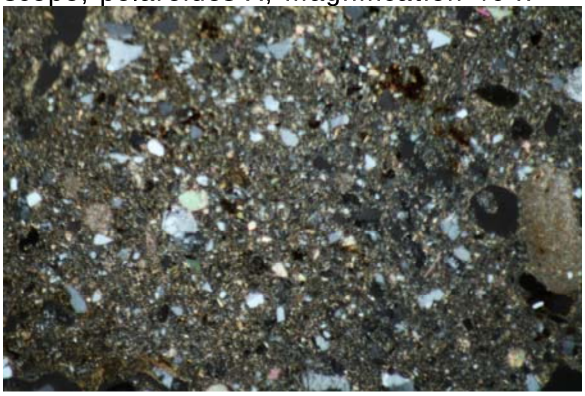

Photo 1C Structure of geological layer 4 Polarizing light microscope, polaroides X, magnification 40 x

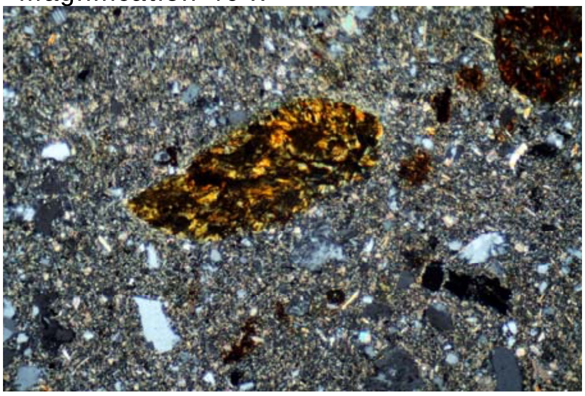

Photo 1D Structure of geological layer 3 Polarizing light microscope, polaroides X magnification 40 x

The most important difference between natural layer no 6 and geo-archaeological layers present above layer no 6 concerns the presence of fragments of bricks. They are present only above layer no 6 confirming anthropogenic origin of layers 5-3.

Performed examination of layers no 6-3 showed similarity of mineral composition of layer no 6 to mineral composition of brick with the edge suggesting use of local clay for production of this type of bricks. Similarity of composition of layer no 6 and brick with edge confirms additionally the presence of skeletons of the same species of foraminifera.

Table 1. Mineral composition of geo-archaeological layers. (Vol.%). See profile Fig.2

Component	Layer no			
	6	5	4	3
Clay minerals	83,7	82,7	67	73,5
Quartz	14,8	28,6	24,3	18,5
Plagioclases	0,7	0,2	0,7	0,3
K-feldspars	0,4	0,1	0,1	0,1
Calcite	0,1	2,1	3,2	4
Fragments of bricks		5,2	4,1	2,8
Micas	0,2	0,3	0,3	0,2
Organic components	0,1	0,8	0,3	0,6

Because of very fine character of clay minerals sample representing layer 6 was additionally examined using X-ray method . Obtained X-ray pattern indicate that natural-clayey mud is composed of clay minerals, quartz, feldspars and calcite (Fig. 3 - natural). Clay minerals are represented by smectite-chlorite or smectite - vermiculite mixed layer mineral (Fig. 3 upper pattern glycolated). This means that local clayey-mudstone may swell if it’s wet. This feature of natural sediment is very important because churches were build on geological layer which may swell if they are wet. It was probable the reason of destruction of churches . After rains the mud underlying church swells and walls may collapse. On the other hand similar effects may create the use of local clay for the construction of walls of early medieval church (E.M.CH.). Details will be presented at separate publication (Part II).

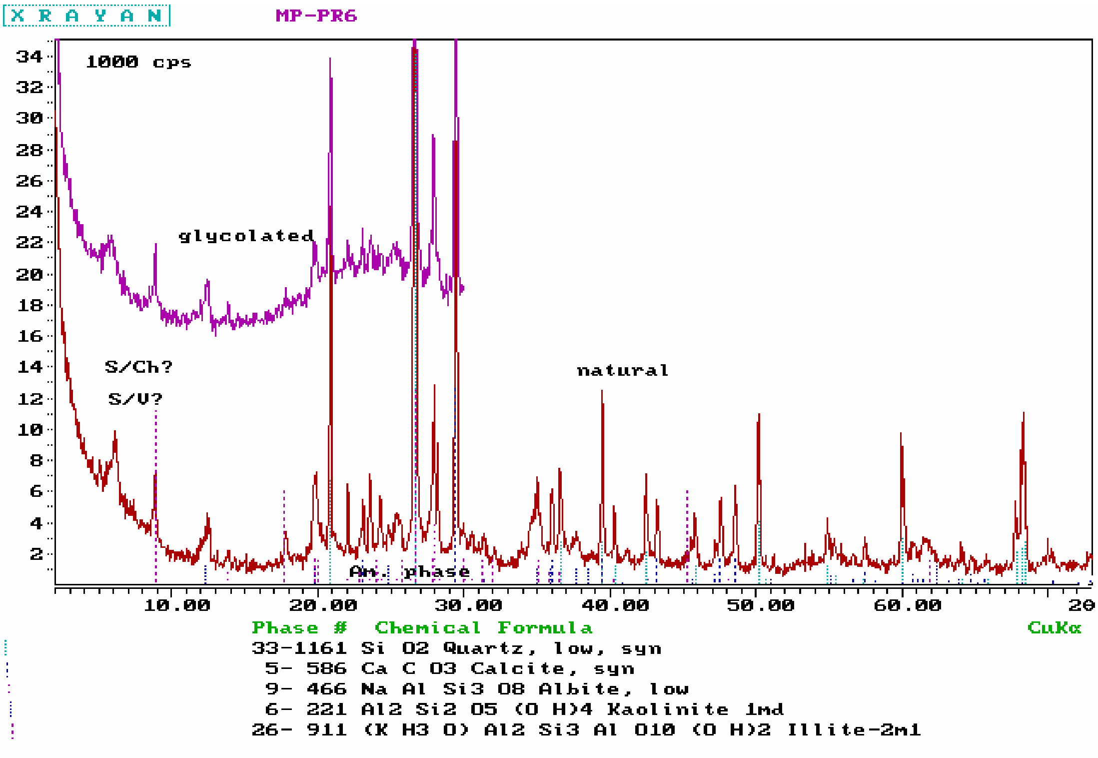

Fig. 3 X-ray pattern of natural gray clayey-mudstone 9 (layer no 6 – see Fig. 2)

This identification was very important because of similarity of clay minerals present in this sediments and in mortar used for construction of walls of Early Medieval Church (details will be presented at part II – under preparation)

Profiles of selected walls (A1-A-4, Fig. 1) - byzantine church (B.CH.) and their reconstructions

Point A1

Profiles of walls of church help understand the sequence of construction of parts of byzantine temple. They constitute the base for reconstruction of destroyed elements of church. Because of this, four points (A1-A4) of church were examined in details (Fig. 1).

Profile A1 is located at northern wall of B.CH. at the place where the entrance to the temple was located (Photo 2, Fig. 4). Investigation of this place helps to determine west wall of entrance where is seen wall build of bricks with edge connected with wall build of plate brick and stone. The structure of entrance suggest the presence of one step leading down from area surrounding the temple.

Photo 2 Point A1 (see-Fig. 1). West wall of the entrance into byzantine church seen from inter of church. One can see steep into the church (right site of the photo), the wall built of bricks with edge (enface), and part of wall built of stones and bricks (left part of the photo).

The presence of entrance into the B.CH. is confirmed by tombs located around the church. Only at this place (place of entrance) there are not tombs at geo-archaeological layers representing byzantine phase.

On the other hand observation of all profiles document very deep destruction of walls of byzantine temple. This means that construction of Early Medieval Church (E.M.CH) was done only on relicts of byzantine temple. This phenomena confirm that degree of destruction of byzantine temple before the build of E.M.CH. was great.

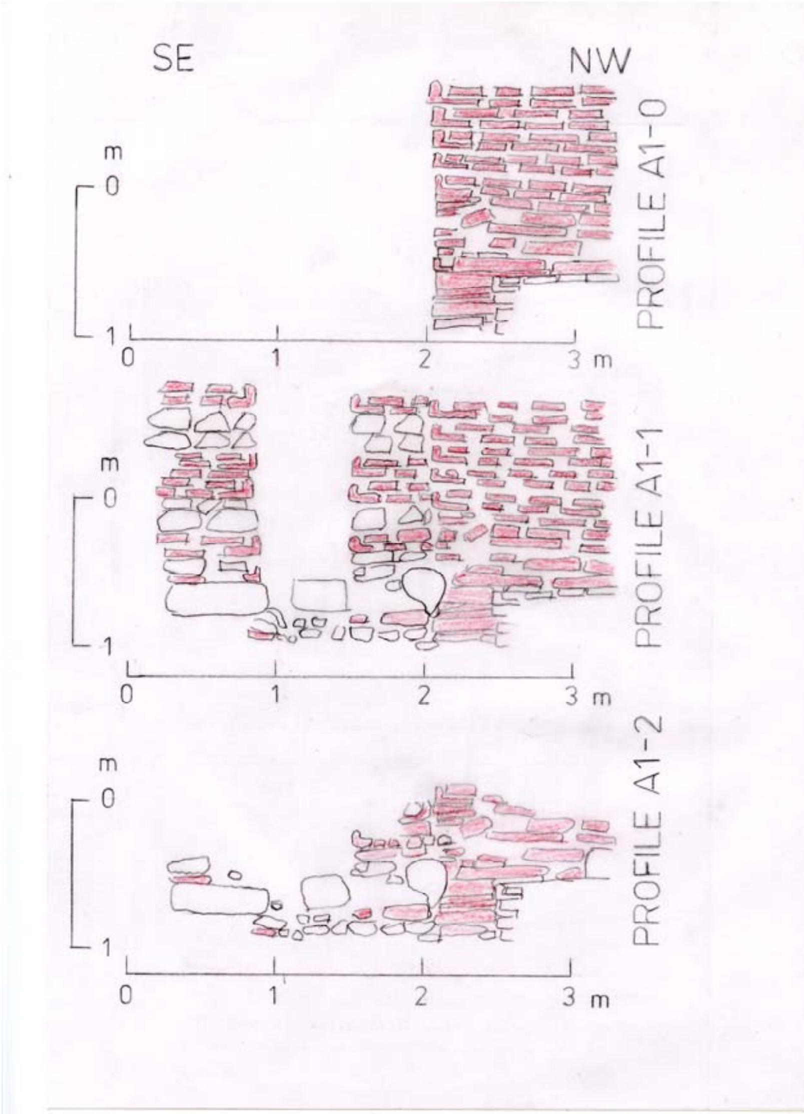

Fig. 4 Present profile A1-2 (see fig. 1) at the entrance leading into the B.CH. (seen from church). One can see steep leading into the church, wall built of bricks with edge (left side) and rest of wall built of stone and plate bricks (separating apse of church from rest of church).
A1-0 – reconstruction. Phase of construction of west part of entrance with step (built of bricks with the edge).
A1-1 – reconstruction. Phase of construction of wall (built of stone and plate bricks) (separating apse from rest of the church).

Point A-2

It is fragment of the wall with entrance into B.CH. with fragment of travertine column and vertical contact of wall built of brick with edge with wall build of stones and flat bricks
(Photo. 3, Fig. 5).

Photo 3 East part of point 2. Rests of strongly damaged walls of B.CH. with fragment of travertine column.

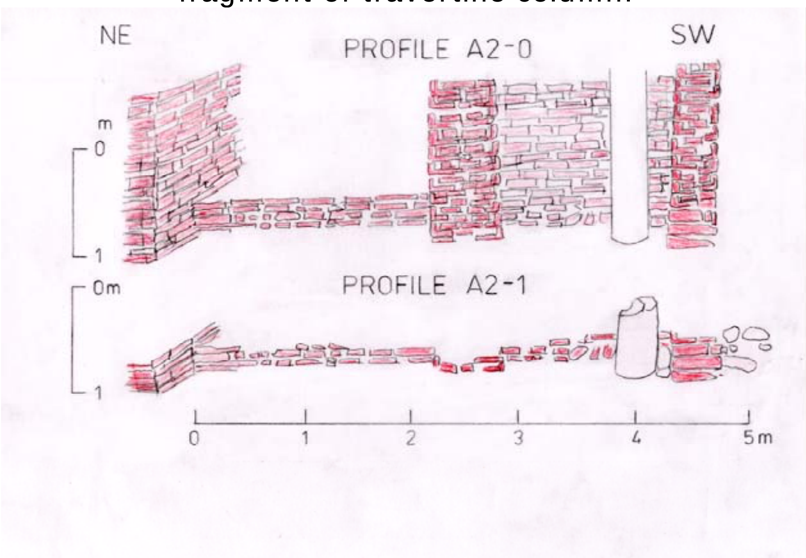

Fig. 5 Present profile A2-1(see fig. 1) of North wall at the entrance leading into the byzantine church (left part of drawing) seen from the church.
A2-0 - reconstruction. Entrance into the B.CH. seen from church.

Point A3

This point is located at the place of binding of two walls of B.CH built using various materials (Fig. 1) i.e. wall built of bricks with edge and wall built of stones and bricks between apse and rest of church (Fig. 6)

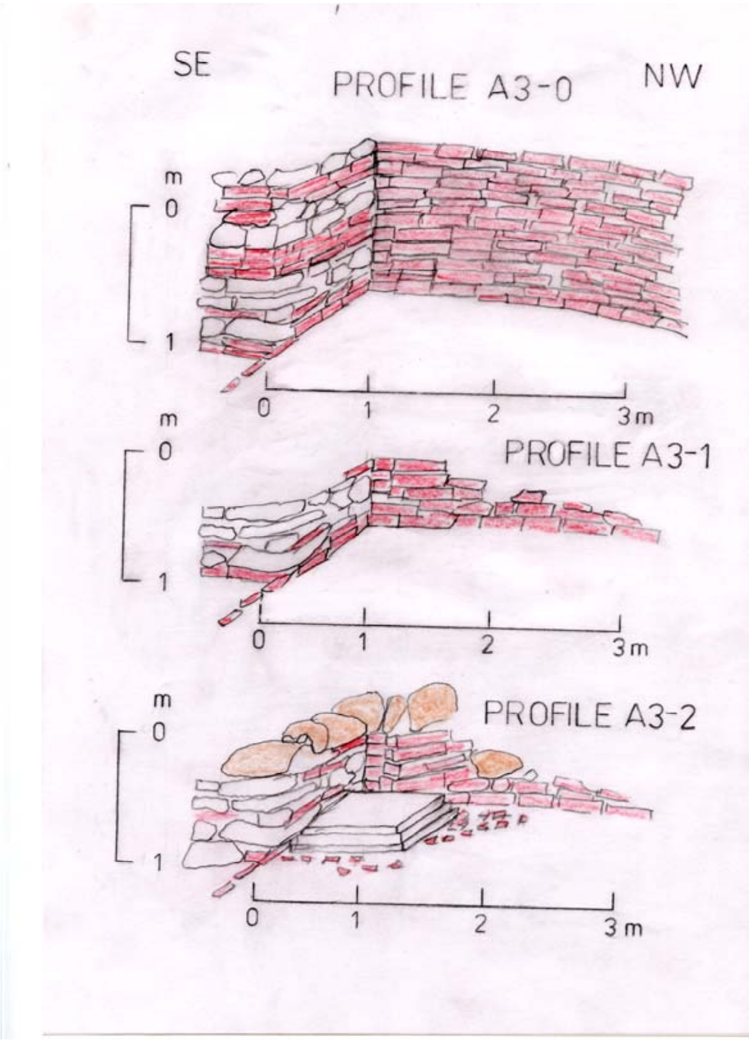

Fig. 6 Present profile A3-2 (see fig. 1) of the contact of apse with wall separating apse from rest of B.CH.
The rest of wall build of bricks with edge (apse) contacting with the wall built of stones and plate bricks. Above rests of B.CH. wall one can see river cobbles (brown) used for construction of Early Medieval Church (E.M.CH.).
A3-0 – reconstruction. Phase of functioning of B.CH. The place of binding of apse built of bricks with edge with wall built of stones and plate bricks.
A3-1 – reconstruction. Phase of destruction of B.CH. at point A3 before construction of wall of E.M.CH.

Point A4

This point (Fig.1) is especially interesting because of complicated structure of wall present there (Photo 4) One can see damaged old byzantine wall built of plate bricks and stones contacting with rubbish and present above wall of E.M.CH. Central part of this wall is especially interesting. The structure of wall suggest the transition from the main part of B.CH. to the room located to the South from southern wall of B.CH. (Fig. 7)

Photo 4 South wall of B.CH. showed at fig. 1.The contact of byzantine wall built of stone and plate bricks (right side of pho) with gray mud and rubbish (central an left side of profile) filling up the entrance to not examined space

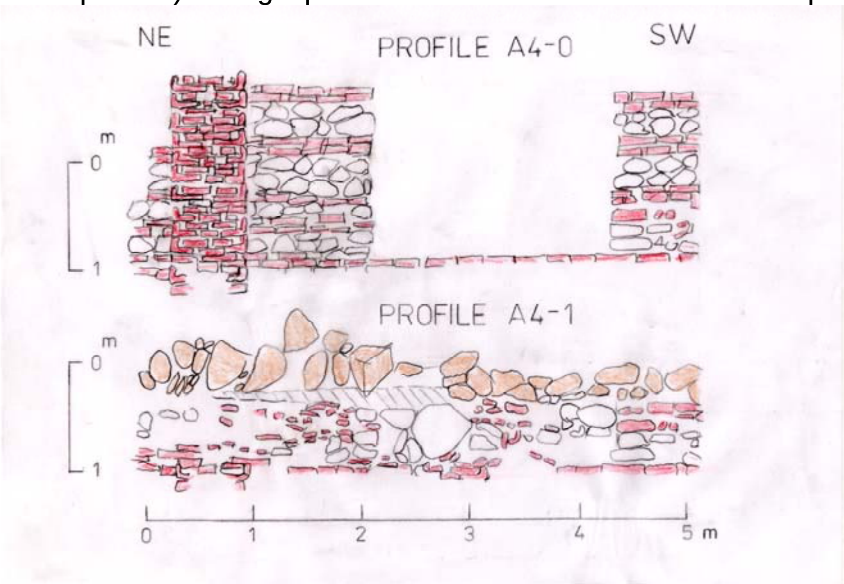

Fig. 7 Present profile A4-1. Damaged rest of wall of B.CH. built of stone and plate bricks with space filled up with gray mud and rubbish. Above one can see brown river pebbles used for construction of E.M.CH. Between wall of E.M.CH and present below remains of B.CH. one can see plaster made of clay and calcite (marked) used for preparation of surface under the wall of E.M.CH.
A4-1 reconstruction. The same place. Transition into next room (?) located South from wall of B.CH.

Types of wall binding

Observation of B.CH. construction help select various types of walls and various types of wall binding (Fig 8)

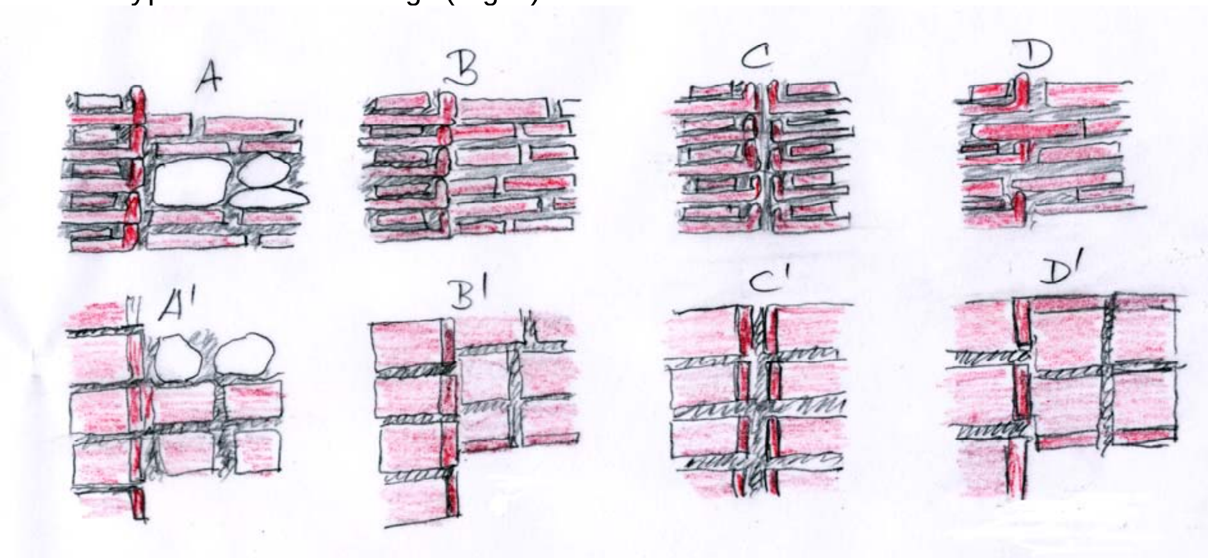

Fig. 8 Various types of walls and wall binding in B.CH.
A,B,C,D – cross section of contact of walls build of bricks with edge
A',B',C'D' – - map of walls binding built of bricks with edge

In most cases the walls are only contacting one with another and they are fixed only with the use of mortar. This situation was observed when wall of apse built of bricks with edge was contacting with the wall build of stone and plate bricks - wall separating apse from the rest of B.CH. (Fig. 8A,A') . Other type of binding is seen at the entrance to B.CH. where step is built of plate bricks and only west wall of entrance is built of bricks with edge (Fig. 8B,B'). Only the edge of step was built with the use of bricks with edge.

There are other types of binding of walls. For example the walls build of bricks with edge contact one with another as shows Fig. C, C'. Corners of church where bricks with edge are contacting, as shown at fig. D, D', where walls are really fixed one with another are especially interesting.

Summarizing one can say that walls of B.CH. are constructed of three main types of brick i.e. bricks with edge, plate bricks and thick bricks with traces of fingers. Results of investigation of these bricks are presented below. Walls are built of bricks –only or are built of bricks and stones (limestones). These elements i.e. bricks and stones are cemented with calcitic mortar and coated with calcitic plasters (see below).

Bindings of most of walls are done with the use of mortar i.e. they not interfere one to another but "stay" separately.

Mineralogy of materials used for construction

A. Bricks

Macroscopic observation of byzantine bricks confirm that they do not only have various size and shape (Photo 5A-D)but their mineral composition is also different. (Tab. 2A-D, Fig, 9A-D)

Photo 5A Damaged brick with edge

Photo 5B Crushed plate brick

Photo 5C The fragment of thick brick with traces of fingers

Photo 5D The fragment floor terracotta

The differences concern mostly relation between thermally changed clay minerals and fine quartz. (Photo 6A-D). Observation of thin sections confirmed that bricks with edge shows mineral composition very similar to clayey mudstone representing geo-archaeological layer no 6 (Fig. 2, Tab. 1). Moreover the same species of small skeleton of foraminifera was identified at brick with edge as well as in natural layer no 6 - clayey mudstone (see photo 6A – skeleton of foraminifera at the centre of photo).

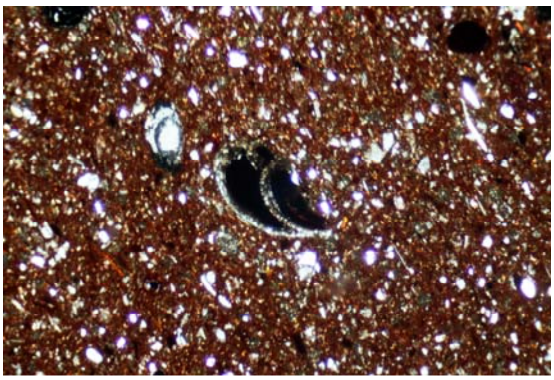

Photo 6A Structure of brick showed at photo 5A Microscope NX, magnific. 60 x

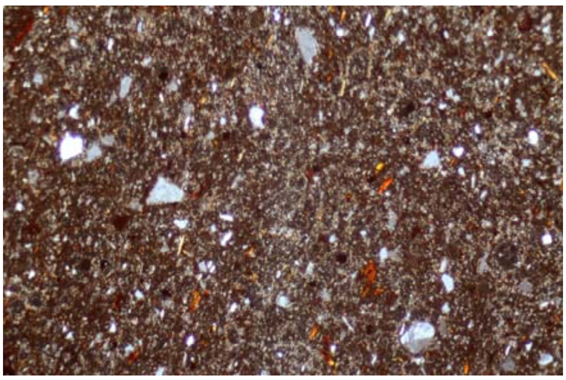

Photo 6B structure of brick showed at photo 5B Microscope NX, magnfic. 60 x

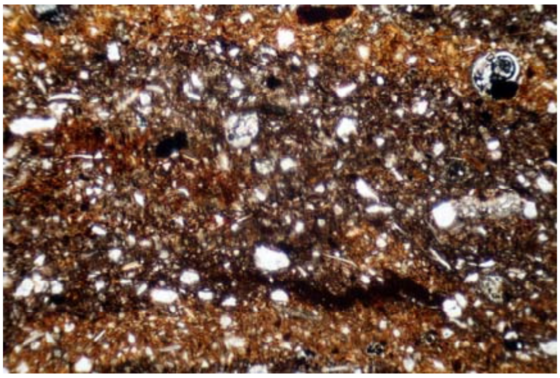
Photo 6C Structure of brick showed at photo 5C Microscope NX, magnfic. 60 x

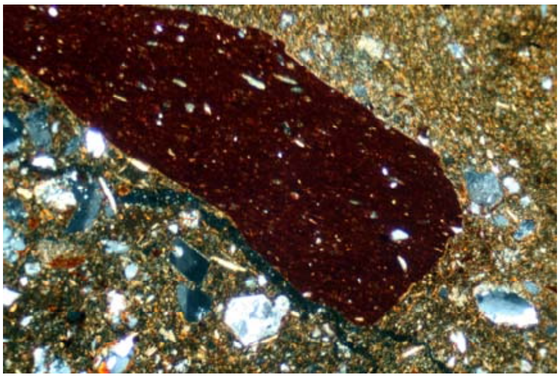
Photo 6D structure of terracotta showed at photo 5D Microscope NX, magnfic. 60 x

The composition of other tested bricks is also differentiated (Photo 6B-D, Tab 2A-D, Fig. 9A-D). Very interesting is terracotta containing fragments of pottery (Photo 6D) and shoving other mineral as well as other grain size composition. Mineralogical data suggest that terracotta was not made of local materials but it was imported from unknown area with clays containing fragments of rocks and more micas represented mostly by muscovite-sericite.

It is interesting that bricks with edge have traces of fingers on the surface (photo 5A) similarly as thick brick (Photo 5C) but mineral composition of both bricks is different (Tab. 2A and 2C) documenting use of various primary raw materials.

Performed investigation of bricks document that for construction of B.CH were used bricks produced locally (brick with edge, plate bricks) as well as terracotta imported from unknown area.

Thermal alteration of clay minerals observed under the microscope suggest that brick with edge and plate bricks were burned at slightly higher temperature than bricks with traces of fingers and terracotta. This suggestion is done on the base of alteration of clay minerals (isotropisation) where first two bricks show slightly stronger thermal alteration. The difference is more-less 50^{o} C, but it is necessary to remember that there are various temperatures at various places.

Table 2A. Mineral composition of brick with edge (no1) – vol.%

Component	Content (vol. %)
Clay minerals (thermally altered)	82,8
Quartz	15,2
Plagioclases	0,8
K-feldspars	0,6
Micas	1,2
Fragments of skeletons	0,2
Opaque minerals	0,3
Fragments of pottery	
Calcite	
Atmosphere of firing	oxide
Temperature of firing	about 800C

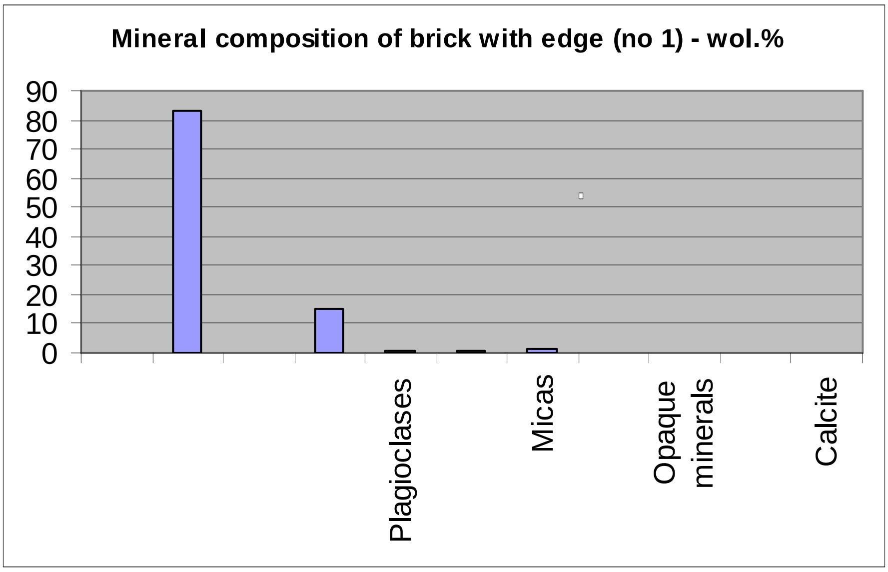

Fig. 9A Diagram showing relation between mineral components of brick with edge

Table 2B. Mineral composition of plate brick (no 2) – vol. %

Component	Content (vol. %)
Clay minerals (thermally altered)	85,8
Quartz	11,8
Plagioclases	0,3
K-feldspars	0
Micas	1,8
Fragments of skeletons	0,1
Opaque minerals	0,2
Fragments of pottery	
Calcite	
Atmosphere of firing	oxide
Temperature of firing	about 800C

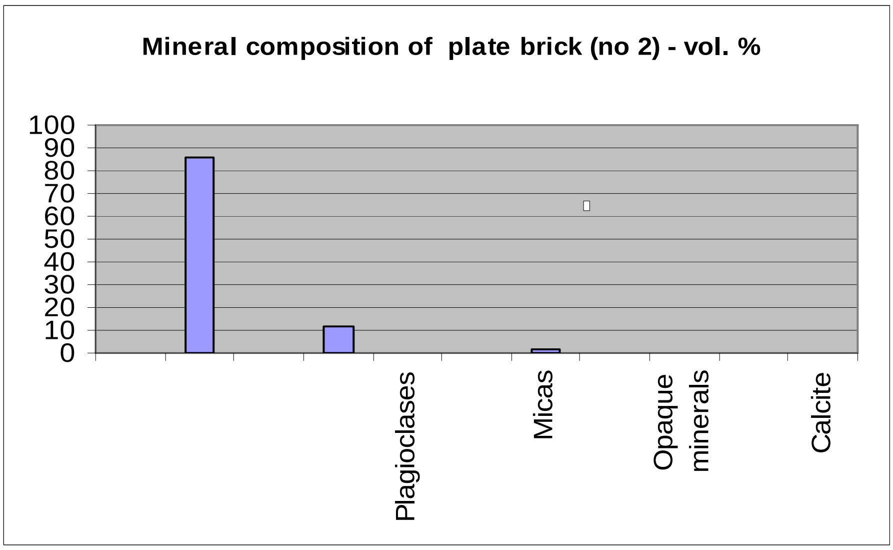

Fig. 9B Diagram showing relation between mineral components of plate brick

Table 2C. Mineral composition of brick with traces of fingers (no 3) vol. %

Component	Content (vol. %)
Clay minerals (thermally altered)	78,1
Quartz	17,3
Plagioclases	0,5
K-feldspars	0,4
Micas	3,4
Fragments of skeletons	0,1
Opaque minerals	0,3
Fragments of pottery	
Calcite	
Atmosphere of firing	oxide
Temperature of firing	about 750C

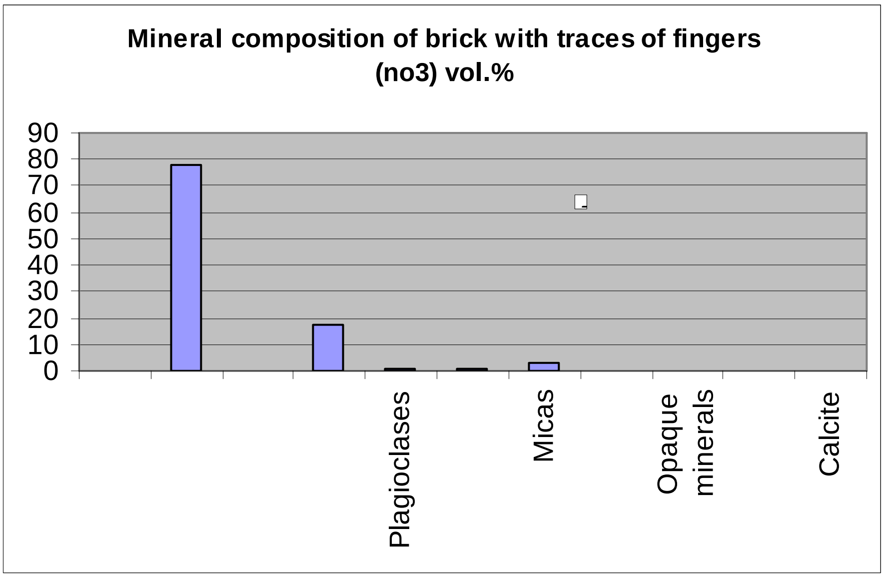

Fig. 9C Diagram showing relation between minerals components of brick with traces of fingers

Table 2D. Mineral composition of terracotta – vol. %

Component	Content (vol. %)
Clay minerals (thermally altered)	71,4
Quartz	15,2
Plagioclases	0,4
K-feldspars	
Micas	2,8
Fragments of skeletons	0,8
Opaque minerals	0,3
Fragments of pottery	6,7
Calcite	2,4
Atmosphere of firing	oxide
Temperature of firing	about 750C

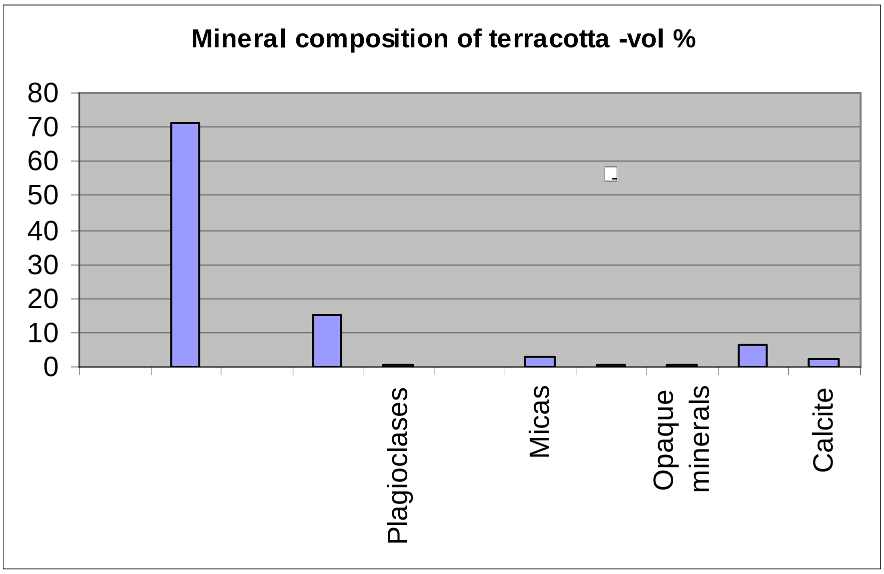

Fig. 9E Diagram showing relation between mineral components of terracotta

B. Stones

On the other hand macroscopic observation of stones used for construction of byzantine walls suggest they are differentiated. They are represented mostly by light limestones most probably not local but transported from not long distance.

Examination of stones present at the wall build of bricks and stones were performed using polarizing light microscopy. Observation of thin section (Photo 7) showed the presence of fine crystallized calcite cut with rare veins of coarse crystalline calcite. At calcitic background one can see black small spots of opaque minerals represented mostly by iron sulphides.

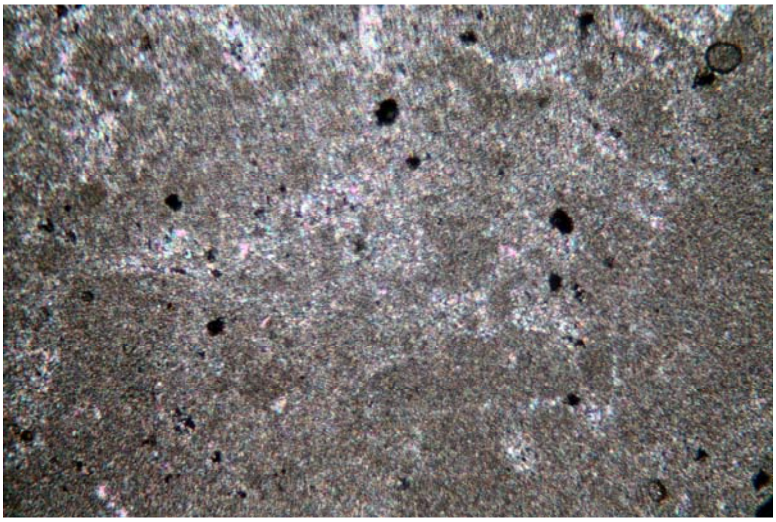

Photo 7 Structure of limestone used together with bricks for construction of wall of B.CH. Polarizing light microscope, polaroides X, magnification 60 x.

More detailed studies of stones of B.Ch. used for walls construction have to be performed in future on more samples.

C. Plaster

The plaster for the examination was collected from the wall of B.CH. apse. Microscopic investigation of thin section of this plaster (cut perpendicularly to the wall) showed that base is composed of coarse sand containing grains of quartz, fragments of magmatic and metamorphic rocks, other fixed with calcite and other (Photo 8- central and left part- Table 3, Fig. 10. This mineral composition confirm that sand used for preparation of plaster was probably not local.

Under the microscope one can see two layers coating the plaster (white painting- right side of photo no 8). Older layer (beige) is composed of pure calcite while second younger is composed of calcite and quartz (yellowish). This younger painting is now strongly damaged.

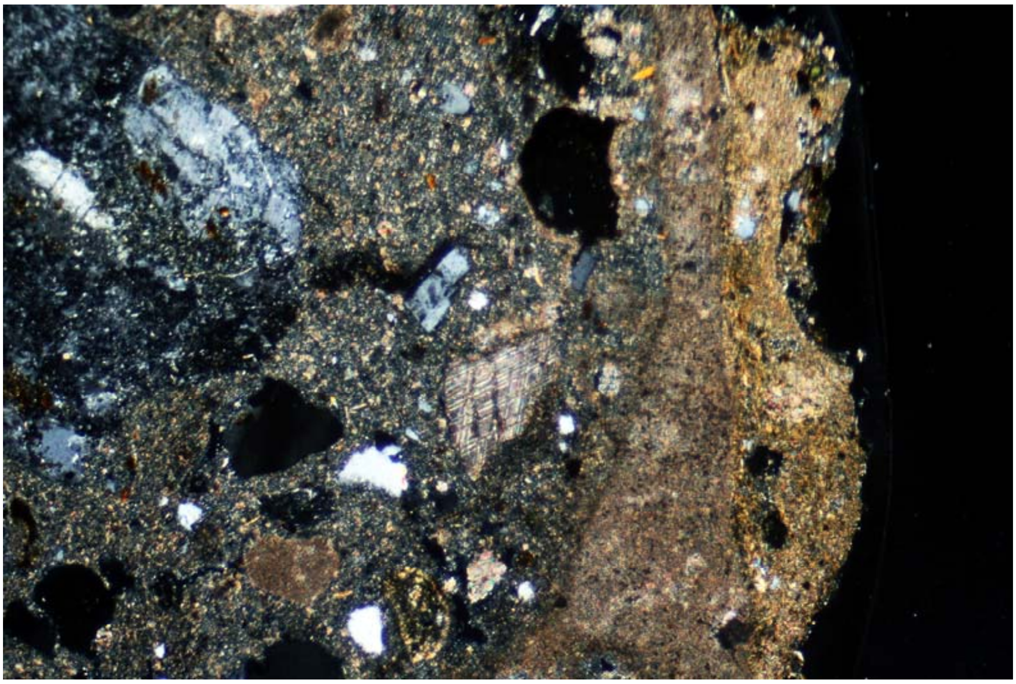

Photo 8 The structure of grey plaster coated with two layers of various mortar – beige and yellowish (right site of photo). Microscope NX, magnific. 60 x

Table 3. Mineral composition of plaster (apse) – vol. %

Component	Content (vol. %)
Calcite mass	23,3
Quartz	68
Plagioclases	2,4
K-feldspars	1,8
Fragments of rocks	2,7
Skeletons of fauna	1,6
Opaque minerals	
Micas	
Calcite	
Organic matter	0,2
Gypsum	

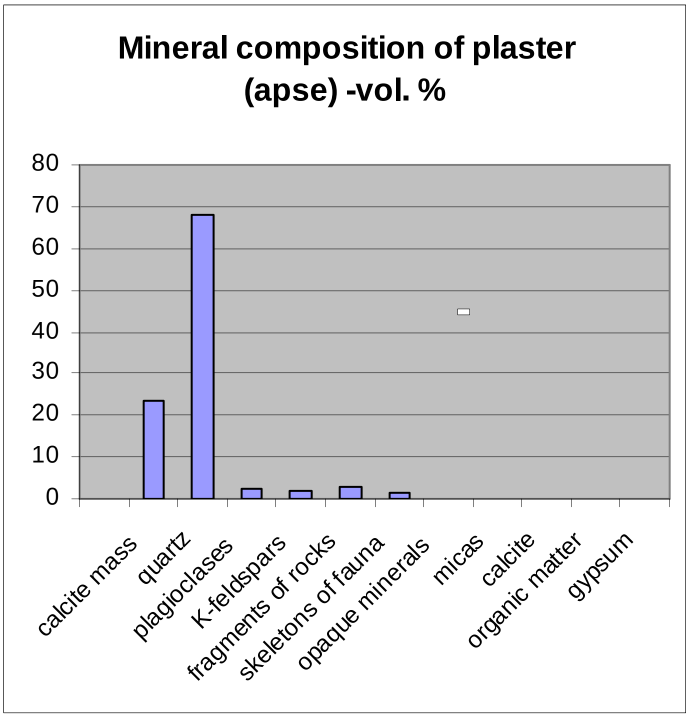

Fig. 10 Diagram showing mineral composition of plaster from B.CH. (apse)

Investigation of plaster confirm minimum two phases of painting of walls of apse of B.CH. Diversified thickness of first painting (beige) documents phase of destruction of walls of B.Ch before another restoring painting of walls of apse (yellowish layer).

Mortar

Sample of mortar was collected from the spaces between bricks of apse.

Microscopic observation showed that mortar is composed of fine grains of quartz cemented with calcite mass (Tab. 4, Fig.11). This cementing calcite mass is not homogeneous because at the background can be observed very fine calcite together with coarse fragments of not well mixed carbonate mass (beige coarse grains –Photo 9). Together these mentioned mineral compounds small mica flakes, rare feldspars and opaque minerals are present.

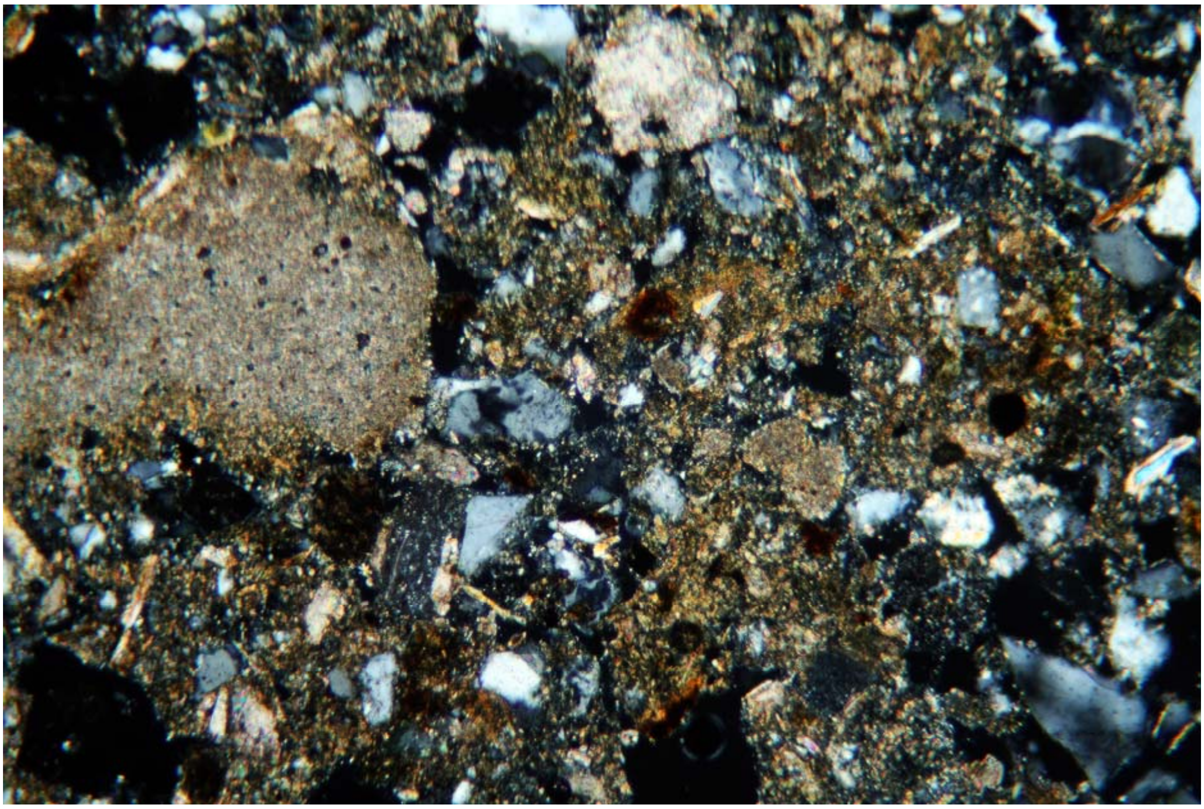

Photo 9 Structure of mortar, clay minerals and fine gray grains of quartz mixed with fragments of calcite added specially for better quality of mortar. Microscope NX, magnification 60 x

Table 4. Mineral composition of mortar – vol. %

Component	Content (vol. %)
Calcite-clayey mass	78,2
Quartz	16,6
Plagioclases	0,5
K-feldspars	0,3
Skeletons of fauna	1,3
Opaque minerals	0,1
Micas	0,2
Calcite (grains)	0,1
Organic matter	0,1
Gypsum	0,4

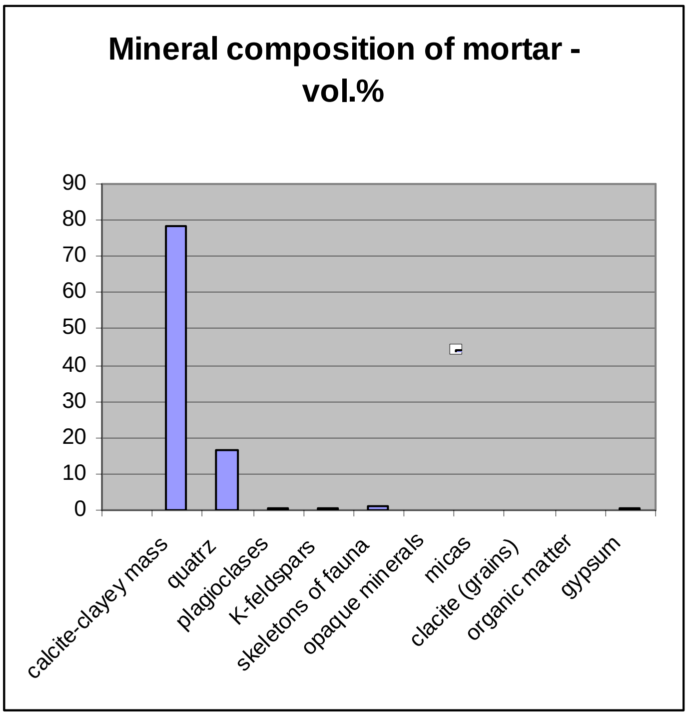

Fig. 11 Diagram presenting mineral composition of mortar . B.CH.-apse

Performed examination document that plaster and mortar have various mineral composition, Structure of mortar and slightly mineral composition are similar to mineral composition of geo-archaeological layer no 4, but contain admixture of artificially added carbonate (calcite)

The results confirmed that quality of mortar used for construction of B.CH. walls is very god. Because of this it was possible use rests of walls of B.CH. as the fundaments for new Early Medieval Church (E.M.CH).

Conclusions

Results presented above are the first part of the investigation of objects examined as PAVA project. Next elaboration (part II) will concern early medieval church (E.M.CH.) constructed over rests of B.CH.

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