Geoarchaeology and Archaeomineralogy (Eds. R. I. Kostov, B. Gaydarska, M. Gurova). 2008.
Proceedings of the International Conference, 29-30 October 2008 Sofia, Publishing House "St. Ivan Rilski", Sofia, 123-125.

ON THE PROBLEM OF MINERAL RAW MATERIALS OF A X CENTURY ARCHITECTURAL MONUMENT: THE DESIATINNA VIRGIN CHURCH IN THE CITY OF KYIV

Nataliya A. Shevchenko[1] , I. A. Cherevko[2]

*[1]National Scientific-Research Centre of Ukraine, Kyiv, Ukraine**;** restorer@i.ua*
[2]National Historical-Cultural Reserve of Kyiv-Pechersk Lavra, Kyiv, Ukraine

ABSTRACT. The technological aspects of building materials have been considered on the basis of a comparative characteristic of the composition of rocks from Starokyivsky Ostanets of the Kyiv loess-like plateau with the mineral content of samples of building materials from basements of the Old Rus nucleus of the X c. architectural monument – the Desiatinna Virgin's Church in the city of Kyiv. The method of mineralogical-petrographical analysis which permitted to determine both the mineral composition and texture-structural peculiarities of the samples became the basic investigation method. Chemical and spectral analyses have been also used. The basic periods of construction and reconstruction of the church from the X to the XIII c. correlated with the data of radiocarbon analysis. The conducted investigations revealed the level and dynamics of the building development in Old Rus, determined the main technological methods and confirmed the claim about the use of plinth and mortars of the local mineral raw materials for the manufacture of building materials.

Introduction

The construction of Desiatinna Church, the first Christian stone temple of the X c. in Kyiv, the Old Rus capital, was a very significant event in the history of Christianity formation in the Slavonic lands. It has not only perpetuated a talented tandem of Greek-Byzantine masters with Kyiv architects but also laid the foundation of an original school of the Old Rus building techniques and technologies. While the construction of the St. Sophia"s Church in Kyiv became a hymn to the heyday of the age of Yaroslav Mudry (Yaroslav the Wise), the Desiatinna Church was an attempt of pioneers, an approval of the intention, the merge of modern and ancient.

This is reflected in changes made during the temple construction represented in the plan of initial basements, the diverse character of used raw materials, and gave rise to some questions which had not been answered so far: what was the initial size of the church, what was the plan, and how was it followed? The history of the long-suffering Desiatinna Church was connected to global destructions even in the period of the Kyiv Rus existence and with its subsequent numerous reconstructions the original appearance of the church has changed beyond recognition. Our contemporaries can see only certain fragments of the destructed basements.

Geological characteristics of Starokyivsky Ostanets

The area of *Starokyivsky Ostanets* which occupies the Northeastern part of the Kyiv loess-like plateau became a place for the Desiatinna Church in Kyiv. The plateau ends in a precipice to the East towards the Dnieper River valley and to the West towards the Goncharny Yar (Potter"s Ravine) thalweg. Absolute marks of the surface area are 180-184 m. At the church construction time the Starokyivska Gora (Old-Kyiv Mountain) had steeper precipitous slopes both on the Dnieper side and on the side of Goncharny Yar. The mass of the filled and diluvium soils, which now cover the slopes almost entirely with about 1 m thick layer on steep areas, and about 7-12 m at the foot, was practically absent. Geological strata cropped out in ravines that allowed the first builders to excavate raw materials just on the spot. The bottom of the Goncharny Yar was 7-10 m below the present level, which is proved by the thick mass of fill-up soils and remains of kilns. Paleogene, Neogene, and Quaternary deposits took part in the geological structure of area up to the Dnieper shore line.

Investigation methods

Extensive archaeological investigations of preserved fragments of the Desiatinna Church basement were carried out repeatedly, from the beginning of the XIX century. The recent excavations started in 2005 with the aim to designate main historical periods of the church construction both in its earliest original size and in its later reconstructions. Samples of plinths and mortars of basements were selected in the process of study for conducting a complex of scientific investigations.

The use of such innovative method of dating as the method of radiocarbon analysis which reflects the dependence of real historical age of the samples on radiocarbon age permitted to date the samples from certain time periods.

Geological conditions of the Desiatinna Church region, structure peculiarities of the deposits and their mineral content helped to elucidate a number of problems concerning possible sources of raw materials used in the manufacture of the construction materials.

The methods of optical microscopy combined with a number of physical and chemical analyses allowed to reveal the basic properties, quantitative and qualitative composition as well as the texture-structure peculiarities of the materials. The method of mineralogical-petrographical analysis which is traditionally used by geologists, when investigating composition of rocks and minerals, was successfully introduced into the practice of technical and technological investigations of construction materials and ceramic objects of Tripolie monuments from the 1940s. In the1970s this method was approved by researchers of the technological laboratory (led by Yu. N. Strilenko) of the Kyiv Scientific-Research Institute "Ukrproektrestavratsiya", when investigating the composition of materials from the Old Rus monuments of Kyiv: St. Michael Gold-domed Cathedral, the Assumption Cathedral of the Kyiv-Pechersk Lavra, the Vydubichi Monastery, and many others. In accordance with their procedure the samples of plinths and mortars of the Desiatinna Church were investigated for the first time in the reflected light with the help of a binocular stereoscopic microscope MBS-10. A thin section specimen was made of each sample. It was investigated by the means of polarization microscope Polam L-213 in transmitted light.

Composition of the wall material – plinths

As a result of the investigation the samples were separated into groups according to common substance composition, structure peculiarities with allowance for physical properties and their production process.

The first group was represented by samples of the so-called "fine" plinths (A-8/1, A-8/2, A-8/3, A-8/4, A-4a) which thickness did not exceed 2-2.5 cm. Their light-grey colour with brown tints was determined by peculiarities of mineral composition of the initial raw materials, i.e. by considerable calcium carbonate impurity reaching 20% and above. Clayey matrix of pelite dimension is polymineral, containing small amount of kaolinite, hydromica and sericite. Calcite is distributed uniformly in a form of micro-fine-granular aggregate accumulations about 0.1 mm in size. The depleting substance makes 15-20% and consists of angular quartz-feldspar fragments of aleurite fraction 0.1 mm in size. The addition of low amount of semi-nodule quartz fragments of psammite fraction with grain size within 0.5-0.1mm does not exceed 3-5%. The depleting material is genetically bound to enclosing clayey matter. Plant organics is present in a form of rarely occurring single remains of chared black detritus 0.2-0.25 mm in size. Most of the plant organics has mineralization traces. High strength of samples and their non-uniform colour suggests high quality of manufacturing.

The second group included the samples of "fine" plinth (A-9, A-10, A-11, A-12, A-6a, A-7a). The thickness of the samples from this group varies within 2.0-2.5 cm. They differ from the first group by their brownish-rosy colour, determined by poly-mineral composition of the clay mainly containing hydromica and small quantity of kaolinite, while the first group of samples contain considerable amount of calcium carbonate. The latter occurs there in a form of fine-grained inclusions and makes only 1-5%.The development of secondary calcite (1%) is observed in pore spaces and in fissures. Aleurite (<0.1 mm) and psephite-psammite (0.1-2 mm) fractions of terrigenous quartz-feldspar material and detritus of ground weathered granite serve as a depleting agent, and they make 30%. The former prevails considerably and is genetically related to clayey component, the latter was probably a special depleting addition, which also performed the function of fusing agent. Besides, the angular fragments favoured a higher strength of the article. The organic substance is presented by two varieties: fine-dispersed impurity and small remains of carbonized plant detritus 0.5-1.5 mm in size with prevalence of elongated and oval shape. The distribution, shape and size of the remains can suggest for artificial addition of organic additions to the plinth paste. The anisotropy of the clayey component and non-changed optical constants of calcite grains suggest relatively low (in the present sense) temperature of burning (probably within 850-900^{o}C).

The third group is presented by 50 cm thick samples A-1a, A-3a, of reddish-brown colour which are characterised by non-uniform colour and clotty micro-texture that is determined by low-quality stirring. High strength of the samples is an evidence for high quality burning. The main component making 50-55% is a polymineral clayey substance of pelite structure which contains kaolinite clots, hydromica scales and essential, about 7-10%, impurity of elongated-bent scales of reddish-brown biotite. The depleting material makes 40-50% and it is presented by terrigenous material of quartz-feldspar composition, granite and gneiss-like rock fragments. Granulometric composition of the depleting agent corresponds to psephite-aleurolite fractions including all the granulometric series with prevalence of the latter. Plant organics is present in a form of shapeless carbon particles 0.5 mm in size and non-uniformly scattered pelite formations.

Mineralogical-petrographical analysis with the use of results of spectral analysis was carried out to obtain objective information. The spectral analysis has shown high content of silicate component: Ca and Mg with average value of Fe in the group I samples compared with groups II and III samples. A higher content of Al is a characteristic of the latter. The difference of element composition is connected to the difference of qualitative composition of raw materials: thus clays of the upper part of geological section were used as a binder in the samples of group I for manufacturing the plinth, while in the group II and III they used the clays from the lower part of the section: kaolin and mottled clays.

In accordance with results of chemical analysis the ratio between silica and alumina, and the high content of magnesium suggests a lower content of kaolinite in clayey substance of group I samples, which mainly consists of montmorillonite and hydromica group minerals. For mineral composition of clayey substance of groups II and III the main part of clayey minerals is presented by kaolinite and hydromicas.

Substance composition of mortars

The fourth group is composed of the samples of mortars (A-2a, A-5a, A-11a, K-05/11a, K-05/14), which, in accordance with the production technology, belong to the so-called "tsemyankas". These mortars are characterized by the use of lime binder and special filler which consists of fragments of ground ceramic material. As a result of these components interaction the mortars acquire high strength and hydraulic properties. Such a technology is characteristic of Greek-

Byzantine architectural monuments of earlier periods and confirms historical information on participation of Greek masters during construction of the church.

The samples are distinguished within the group by the quality of ceramic fragments and by the quantitative ratio between the binder and filler. Thus grey colour with yellowish-brownish tint and very high strength are characteristic of the samples A-11a and K-05/11a. Considerable addition of silica (up to 20%) is observed in the lime binder. Acute-angle ceramic fragments of pale-yellow, light-brown and orange colours consisting of ground fragments of thoroughly burned preliminarily elutriated fat clay serve as a depleting material. These mortars belong, most probably, to the initial period of construction and are characterised by the addition of not only specially prepared tsemyanka, but also the silicon-containing rock. Sample A-5a is rose-coloured. Its strength is something lower that is conditioned by the presence of clay addition to the lime binder. Tsemyanka fragments in a form of burned loam and ground limestone are used as a depleting material. Like the mortars of other monuments, e.g. St. Sophia's Cathedral and the Golden Gate in Kyiv, the above mortars are characteristic of the monuments of the XI century.

Sample A-13a is distinguished by brownish-red colour. The lime binder includes an equi-dimensional filler in a form of fragments of burned loam, 30%, and ground plinth, 70%. Inhomogeneous composition of tsemyanka, i.e. the additional use of plinth parts is characteristic of the monuments of the XII c.; since the middle of the century the ground plinth completely substituted tsemyanka which was manufactured of the loess-like loam.

Sample A-2a is brownish-red and is characterized by a breccia-like texture and by average (to weak) strength. The specific texture of the sample is determined by the presence in the lime binder of fragments of ground tsemyanka mortars from earlier destroyed parts of the church. Qualitative composition of the filler is rather variegated which is connected to the violation of the traditional process of the tsemyanka mortars manufacturing and the use of secondary raw materials. Such mortars probably belong to the period of the church restoration after its destruction.

Technical and technological peculiarities of the construction materials as one of the dating characteristics of the monument construction stages

The substance composition of the group I plinths suggests the use of low temperature raw materials for their production, and together with the little thickness of plinths it testifies for a more complex technological process of their firing. A considerable addition of calcite in the composition of the ceramic paste dictated the narrow range of the firing temperature of 800-900°C, since the exceeding of this temperature can result in calcite decomposition with the increase of volume, that, in its turn leads to the product deformation. Lower temperature leads to the weak firing of the crock and a decrease of mechanical strength of the object. On the other hand, the high amount of calcite in the clay mass also weakens the mechanical strength of the object. Such temperature conditions required the use of special clay applied for low temperatures and minerals of the montmorillonite group correspond to such clay. Thus, the production of plinth was a rather labour-consuming process. The first group of samples (in accordance to their mineral composition and texture-structural characteristics) are related to the initial stage of the construction and dated to the X c. that was also confirmed by radiocarbon analysis.

In the further XI-XIII c. the construction of the whole complex of new architectural buildings and reconstruction of the initial size of the Desiatinna Church resulted in the perfection of the structure of kilns, excavation and processing of raw materials. One could observe the improvement of equipment and production technology of construction materials that allowed using more "high-temperature" clays. The latter is evident from the mineral composition and physical and chemical properties of the samples from groups II and III, characterising the composition of plinths of the later size of the Desiatinna Church. Mottled aleuritic clay sometimes enriched with mica was used for manufacturing such plinths. Mica favoured a decrease of firing temperature, but in contrast to clay with calcite it did not require such thorough following of the production process specifications, simplified the firing process while preserving a rather high manufacture quality. The group II plinths, in analogy with materials from the Old Rus monuments in the city of Kyiv from the X-XIII c., were dated to the XI c., while group III – to the XII century. The method of radiocarbon analysis of the group II plinths has dated them to the XI c., and group III plinths – to the late XI and XII centuries.

Conclusion

The conducted investigations testify for the existence of traditional technologies of excavation and processing of mineral raw materials and production of original construction materials in the Kyiv Rus area of the X-XIII centuries. The process of production of tsemyanka mortars which was first used in the period of construction of the Desiatinna Church continued its existence to the end of XIII century. It was then lost, and was never renewed. The Desiatinna Virgin's Church was ruined completely in 1240 during the Tartar-Mongol invasion and served as the last sanctuary for Kyivites. It was reconstructed repeatedly but with absolutely new appearances.