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The Influence of the Material-structural Characteristics of Travertine, Limestone and Alabaster on the Features of Their Use in the Construction of the Assumption Cathedral in Princely Halych

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Abstract: The authors established the relationship between substance-structural characteristics of natural stone – alabaster, limestone and travertine, and the features of its use in the construction of the Assumption Cathedral in Princely Halych. The authors draw on data from archaeology, geology, the latest technological research, and the method of comparative analysis. The article shows the features and continuity of the materials application in the region construction.

Thanks to the comprehensive studies of travertine, limestone and alabaster blocks, it was possible for the first time to discover and identify specific sources of origin of the main building materials of the Assumption Cathedral of Princely Halych. And probable routes of stone transportation to the cathedral's construction site are also outlined. The conducted research also indicates that since the 12th century, we can speak about the stability and continuity of the travertine use in the construction of the region.

Keywords: Galicia-Volyn principality, Assumption Cathedral, fresco painting, travertine, limestone, alabaster

Introduction

After many years of research on the Assumption Cathedral of Princely Halych, a monument of great importance to Ukrainian history and culture, there are still questions that require further investigation. This also applies to the construction materials used in its building. Therefore, the authors turn to data from archaeology, geology, modern technological studies, and the method of comparative analysis.

Purpose of work

The aim of the article is to investigate the influence of the material-structural characteristics of the main construction materials (travertine, limestone, and alabaster) on the features of their use in the construction of the

Assumption Cathedral in Princely Halych, to identify and determine specific sources of their origin, and to outline probable routes for their transportation to the construction site of the cathedral.

Analysis of recent research and publications

Based on iconographic, literary, and archaeological sources, architectural and art historians (notably Volodymyr Yarema, Yuriy Dyba, Ivan Mohytych, and Mykhailo Rozhko) have been able to reconstruct the appearance of the now non-existent building to varying degrees of hypothetical accuracy. Mykola Bevz, Volodymyr Bevz, Vasyl Petryk, and Yuriy Lukomsky have outlined the challenges in researching, preserving, and conserving the Assumption Cathedral [1].This is the only known monument of princely Halych for which, based on the entire body of conducted scientific research, it can be confidently stated that it featured a comprehensive ensemble of fresco decoration (from top to bottom [2]). The technological features of the frescoes, mortars, and plasters of the Assumption Cathedral were highlighted in scientific publications by Viktor Melnyk [3]. In-deth scientific and restoration studies of the remnants of the Assumption Cathedral's masonry were conducted by Kyiv researchers Roman Hutsulyak and Yulia Strylenko, who published a series of articles on this subject [4]. Archaeological materials related to the Assumption Cathedral of the second half of the 12th century in Halych and its decoration have been known since the discovery of the structure's remains. However, there is no chronicle evidence regarding the materials used in the available sources.

For decades, professional publications have consistently claimed that limestone for the cathedral's construction and decoration was transported from the vicinity of Mykolaiv on the Dniester, specifically from the village of Demnya, as limestone is absent in the immediate surroundings of Halych. It is worth noting that a separate study has been devoted to the plaster and fresco painting that covered the stone blocks used in the construction of the Assumption Cathedral [3, pp. 96–97].

Based on the conducted studies of the construction materials and plasters, it has been proven that the interior of the cathedral was fully painted, as fresco remains were found both on the lower blocks (made of limestone and alabaster) and on the vault blocks carved from porous Podillian travertine. This was rightly noted by Y. Pasternak [5, p. 84], relying on the research of his brother, Severyn Pasternak [6, p. 200]. This construction technology convincingly demonstrates the systematic and professional approach of the builders to arranging the walls and vaults.

Mineralogical and Petrographic Studies of the Assumption Cathedral's Building Stone

Preliminary studies of the stone materials used in the construction of the Assumption Cathedral [6, p. 200; 20, pp. 46–47] identified three main types of rock: limestone, travertine, and alabaster.

Limestone is the most widely represented, as visual inspection of the white stone blocks and fresh fractures revealed several variations. Limestone is a relatively soft sedimentary rock, typically white, yellowish, light gray, or light beige, composed mainly of calcite ($CaCO_3$), with a hardness of 3 on the Mohs scale, making it widely used in construction and architecture. It contains impurities in the form of sand and clay particles as well as remnants of limestone skeletons of organisms.

Limestone is one of the most widespread rocks, with numerous deposits worldwide. Limestone quarries are developed in almost every country. It is easy to extract and process, resistant to temperature fluctuations and moisture, and characterized by structural uniformity. It also has high thermal insulation properties. Therefore, it has been widely used from ancient times to the present as an excellent material for constructing buildings, bridges, monuments, and other structures, as well as for creating decorative elements such as columns, facades, and sculptures. Its use in temple construction is particularly notable. A chalk-like white, massive coccolith-foraminiferal limestone is the densest variety identified, as it consists of microscopic organic remains. Despite its density and massiveness, this type of rock is not strong; it easily disintegrates and is unstable at subzero temperatures, especially under conditions of excessive moisture.

More robust varieties include: white, durable, fine-grained, and micro-porous lithothamnion-polydetrital limestone, Gray, strong, fine-grained, and micro-porous limestone with white stromatolites, both of which are

characterized by a significant presence of small quartz grains. The presence of small pores increases their resistance to temperature fluctuations and moisture, improving their thermal insulation properties. Similar characteristics are found in gray, porous, unevenly-grained detrital polydetrital limestone with white inclusions of paleofauna. However, it should be noted that the heterogeneity of the structure, due to the varying sizes of the detrital fragments, leads to anisotropy in the rock's properties [7, pp. 46–47].

In the vicinity of Princely Halych, as well as throughout the territory of the Halych-Volhynian Principality, numerous limestone deposits are known, some of which are still being quarried. Notably, during the princely period, limestone extraction and processing were carried out by breaking stone from horizontally layered strata. The stone was then cut into blocks of the required size and manually dressed. This method minimized structural disturbances to the stone and preserved its durability after processing.

Fig. 9. Limestone blocks with traces of processing (village of Krylos)

The gypsum stone blocks identified among the building material of the Assumption Cathedral of Princely Halych are also characterized by diversity. Gypsum is represented by a cryptocrystalline or fine-crystalline variety of the rock – alabaster. Its deposits are chemogenic formations from the initial stages of halogenesis, accumulated in saline lagoon conditions in regions with a dry and hot climate. Alabaster is characterized by high density and massiveness due to the dense packing of isomorphic small (up to 10 μm) grains, which also affects its hardness, making it considerably harder than coarser crystalline gypsum [24]. The alabaster blocks found among the remnants of the structure show the presence of layers with a different composition. The carved decoration has a variety of colors, primarily white and gray, often with a bluish tint, and sometimes striped or mottled. They are usually massive, sometimes with interlayers of alabaster, gypsum, and carbonate-clay strata, and in some blocks, there are veins of translucent, parallel-fibrous gypsum – selenite, about a centimeter thick [8, pp. 45–46]. The visual heterogeneity of the coloration indicates the presence of impurities, while the structural diversity reflects the varying grain sizes and the presence of layers with different material compositions, which affects the durability of the alabaster, reducing its resistance. This material is sourced from villages near Halych, such as Bowsiv, Viktoriv, Zhuravno, and Sokil [9, p. 213].

Alabaster, like gypsum in general, is vulnerable to the action of water, as evidenced by numerous manifestations of karst formation in areas where gypsum rocks are prevalent. Moreover, under increased moisture conditions, the stone material becomes sensitive to subzero temperatures, and the combined effects of both factors lead to the destruction of the surface areas of the stone and its complete breakdown with repeated exposure to these destructive agents. The use of alabaster in global construction practices has been quite broad and diverse, including the construction of buildings, elements for water supply and drainage systems, cladding, and decorative interior and exterior elements. In our climatic conditions, with high humidity levels and significant daily temperature variations, the durability of the stone is much lower than in warmer and drier regions.

This is likely why the use of alabaster as a building material in later historical periods was quite limited, with its use predominating in cladding and in the production of artistic and decorative items.

Fig. 10. Alabaster detail (village of Krylos)

The travertine (limestone tuff) blocks are not as numerous as other materials used in the construction of the Assumption Cathedral of Princely Halych. Travertines were widely used as building stones in cultural heritage, primarily across the entire Mediterranean region. The use of travertine as a construction and cladding material continues to this day. This is due to a variety of factors, primarily its physical properties and durability. Travertines exhibit a wide range of textures and colors: from the colored varieties of Spanish travertines to the white travertine from Turkey. According to Y. Pasternak, Podolian travertine was used in the construction of the Assumption Cathedral [5, p. 84], however, no precise geographical data was provided by the author regarding its exact origin. The terms "travertine" and "carbonate tuff" are often used interchangeably to describe carbonate rocks formed by water deposits on the Earth's surface. In this general sense, travertines are divided into two geochemical groups: cold-water meteogenic travertines from continental deposits of springs, rivers, lakes, and bogs, and thermogenic travertines, where carbonate deposits are formed by hot spring waters. Meteogenic travertines are known as limestone tuff, while travertine, in the classical sense, refers exclusively to thermogenic deposits. Therefore, it is more appropriate to use the term "limestone tuff" when describing Podolian travertines.

These formations are generally very porous and spongy, containing large amounts of fossil and plant remains, and often include calcified remnants of micro- and macrophytes, and sometimes even invertebrates. The carbon framework rapidly disappears, leaving behind the characteristic highly porous and permeable texture. During diagenesis, limestone tuff undergoes changes, becoming compacted, hardened, and acquiring the necessary physical properties to become a building stone. At the same time, travertines are characterized by parallel structures, so tuffs are usually distinguished from travertines by their comparatively higher variety of macrofossil deposits. The hardness of the stone is variable and largely depends on the post-deposition processes. The structures of travertines and tuffs significantly affect their petrophysical behavior, which is crucial for their correct use in construction. Low-porosity or massive travertines are the most durable, while high-porosity varieties are the least resistant. Layered structures exhibit the greatest anisotropic behavior, which is clearly reflected in the mechanical properties of the stone [10].

In Princely Halych, blocks of gray limestone tuff with a light beige tint were used. These are strong, though somewhat fragile, carbonate rocks with a porous and complex texture, exhibiting varying porosity, which ensures low thermal conductivity, good sound insulation, and ease of cutting. Microscopic studies revealed fine-grained, both homogeneous and complex structures, with the most characteristic structural features of plant forms. The main mineral-forming substance is calcite, which makes up 96–98% of the rock, with clay material and quartz grains present as impurities [11, p. 47]. Due to its high porosity and carbonate composition, this building material is also not resistant to moisture. Prolonged soaking is destructive to it. This likely explains

its use in parts of the building where the risks of prolonged moisture exposure are minimal—such as in vaults and internal elements of the structures [12]. Travertine is most widely used in Italy, due to the presence of the largest travertine quarries in the country. There are cases where the exploitation of travertine deposits has been ongoing since the foundation of cities, and it becomes the main material for all types of construction, as seen in the city of Ascoli Piceno.

The use of porous bricks in the upper layers of ancient Kyiv churches was noted by Mykhailo Hrushevskyi when examining the construction techniques, explicitly linking this practice only to the Byzantine tradition [13, p. 426].

Fig. 11. Travertine block with a complex heterogeneous porous structure (village Krylos)

In addition to the Assumption Cathedral of the princely Galych, two other instances of the use of travertine blocks in the vaults of sacred buildings have been documented by the authors in the western Ukraine. The first such object is the castle chapel (church) of the Holy Trinity in the town of Berezhany in the Ternopil region – a national architectural heritage monument with protection number 641/2 (ID 61-204-0005). It is located in the southwestern part of the castle yard and has typical features of Renaissance architecture with elements of late Gothic and later additions from the Baroque period. The chapel was built simultaneously with the castle and served as a burial place for several generations of its owners. The castle was built on a swampy island between two arms of the Zolota Lypa River, east of the town, which is located at the border between northern Podillya, Galicia, and southern Volhynia [14, p. 258]. The construction lasted about 20 years and was funded by the Great Crown Hetman, the Ruthenian Voivode Mykolay Senyavskyi. The completion in 1554 is confirmed by an inscription on a white stone plaque embedded above the entrance gate of the main southern facade [14, p. 257]. Elements of its vault are made of travertine, although its origin and transportation routes still require further research.

The second object, apart from the Assumption Cathedral of the princely Galych, in which travertine blocks were found in the vaults, is the abandoned castle church of the Ascension of the Virgin Mary of the Dominican Monastery in the Chervone area near the village of Nyrykiv in the Ternopil region. It was built in the late Renaissance style with Gothic elements in 1615, funded by the Lisetsky family [15]. The hewn travertine blocks in the church's vault are tightly fitted together. Additionally, travertine blocks were widely used inside the church. Field studies conducted by Ulyana Borynakh in 2017–2018 revealed that the vaults of the basement rooms, the choir balcony ("choir"), altar, and columns are made of travertine blocks of a characteristic gray-brown color. In some areas, the plaster that covered the blocks has been preserved. The use of travertine for constructing interior elements of buildings is common in Western European temple construction, but plaster covering on travertine columns is unusual, as the structural and textural features of the stone have distinct decorative value.

The described fragments of the Renaissance building in Nyrykiv are quite well-preserved (if such phrasing can be applied to its current condition). The prolonged destructive processes and the lack of special studies

make it impossible to determine at this stage whether there were fresco paintings on them. However, the value of this "technological" evidence lies in the fact that, at least from the 12th century, we can affirm the continuity and uninterrupted nature of the corresponding aspect of the region's building tradition, which also influenced later times.

Returning to the question of the construction of the Assumption Cathedral of the princely era in ancient Halych and based on the results of mineralogical-petrographic studies, the authors made an attempt to find identical material in the natural travertine complexes of the Middle Dniester region to establish the sources of origin, as well as to recreate the probable supply routes for the material to the construction site. Based on the obtained results, the conclusion was made that the travertine blocks found in Krylos are most similar in terms of mineralogical-petrographic characteristics (color, composition, textural-structural features) to the travertine rocks from the village of Porokhova. During the expedition, samples for comparative analysis were taken from a travertine outcrop located at the top of the left slope of the Barish River valley on the southern outskirts of the village of Porokhova near the forest. The length of the outcrop is about 100 meters, and its height is 10–11 meters. It can be assumed that the building material for the cathedral was supplied from the village of Porokhova or its immediate surroundings. The probable transportation route was along the Barish, Dniester rivers, and possibly the Lukva River.

If we analyze the distribution of natural travertine complexes in the Middle Dniester region, it can be noted that the village of Porokhova and the nearby travertine outcrops near the villages of Deleva, Stinka, and Kosmyryn are located the highest along the Dniester River, and thus were the closest to the site of the cathedral's construction. The presence of a travertine deposit here is specifically noted on the website of the Ternopil Regional State Administration [16]. The officially discovered deposit is not being developed, and no signs of current exploitation of the travertine outcrops were recorded during the expedition.

In conclusion, we can say that the use of at least three types of stone (limestone, alabaster, and porous travertine), as well as the high artistic level of the preserved white stone and alabaster details, indicate the Assumption Cathedral as a significant structure in the architectural heritage of princely Halych. Recently, deep and multi-dimensional technological studies of the alabaster used in the construction of the cathedral were conducted by Ulyana Borniak and Vasyl Huliy. The different states of preservation of the alabaster blocks are linked to the structural-textural characteristics of the material. Several morphogenetic types are visually distinguished, which may indirectly point to different sources of alabaster supply [11, p. 46–47]. The study of the alabaster blocks of the Assumption Cathedral continues, and there is hope that they will reveal new pages of the history of this iconic building. It is also worth noting the alabaster details as a significant part of the artistic decoration of the cathedral. The presence of this stone, undoubtedly, was driven by its active use in the construction of this landmark.

Conclusion

Thanks to the comprehensive studies of travertine, limestone, and alabaster blocks, the influence of the material's compositional and structural characteristics on their usage was substantiated. For the first time, specific sources of origin for the main building materials were identified, and the likely transportation routes to the cathedral construction site were outlined. Since the 12th century, there has been a continuity in the use of travertine in regional construction, although such examples are now relatively rare due to the limited scope of local masonry. Western European examples of buildings that used travertine, in our opinion, may point to a certain region in Italy, from which the building tradition likely originated, forming the basis for the construction and decoration of the Assumption Cathedral in Halych. Studies on the stylistics of the cathedral's white stone carvings may also confirm this hypothesis, though this issue is still being worked on and will be addressed in a separate publication. Work in this area is ongoing, with particular attention paid to the analysis of building mortars and fresco plasters. We hope that further research will continue to reveal new aspects of the construction and decoration of the Assumption Cathedral of princely Halych.

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Wpływ właściwości materiałowo-strukturalnych trawertynu, wapienia i alabastru na cechy ich wykorzystania w budowie katedry Wniebowzięcia Najświętszej Maryi Panny w Księstwie Halickim

Streszczenie: Autorzy ustalili związek pomiędzy materiałowo-strukturalnymi właściwościami kamienia naturalnego – alabastru, wapienia i trawertynu, a cechami jego wykorzystania przy budowie katedry Wniebowzięcia NMP w Haliczu Książęcym. Autorzy odwołują się do danych z zakresu archeologii, geologii, najnowszych badań technologicznych oraz metod analizy porównawczej. Pokazano specyfikę i ciągłość wykorzystania tych materiałów w budownictwie region. Dzięki kompleksowym badaniom bloków trawertynu, wapienia i alabastru po raz pierwszy udało się wykryć i zidentyfikować konkretne źródła pochodzenia głównych materiałów budowlanych katedry Wniebowzięcia NMP w Haliczu Książęcym, a także wytyczyć prawdopodobne trasy transportu kamienia na miejsce budowy katedry. Przeprowadzone badania wskazują również, że od XII wieku można mówić o stałości i ciągłości wykorzystania trawertynu w budownictwie regionu.

Słowa kluczowe: księstwo galicyjsko-wołyńskie, katedra Wniebowzięcia NMP, freski, trawertyn, tuf wapienny, wapień, alabaster