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The technology of masonry and processing of stone materials in the buildings of the 13th-century castle of King Danylo Romanovych in Kholm

Abstract. The relevance of the study is conditioned by the great cultural significance of King Danylo's Castle, one of the most unusual architectural objects of the 13th century Rus'. The purpose of the study was to reveal construction technologies, techniques for processing and carving architectural details made of stone, which are used in the construction of castle objects. The research methodology was based on a detailed analysis of the remains of buildings and individual construction or architectural details discovered due to architectural and archaeological research. The study analysed the characteristics of the used natural stones. Archaeological remains of the defensive wall, towers, foundations, and walls of several buildings, the purpose of which has not yet been clarified, present objects created by a highly professional construction workshop. Excavations have revealed a large number of carved decorative architectural details made of glauconitite and limestone, the use of which indicates the richness of architecture and presents specific architectural forms of the Romanesque style. At the first stage, the castle was built only of stone, and at the second stage, brick was also used. The oldest buildings were made of natural glauconite stone. In addition to local green glauconite sandstone, limestone, and fossilised chalk were also used. An interesting feature of the castle is the use of typical Romanesque masonry technology, stone block hewing techniques, and carving of decorative stone details. Based on the results of research, it can be stated that a standard set of hand tools was used. The remnants of carved stone details show the rich plastic structure of the castle's facades and interiors. Similar products and technologies are not found in other castles of Rus' at that time. Finds of masonry tools in the castle ruins suggest that most of the technological process of stone processing

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took place right there in the castle yard. The results of the study allow presenting for the first time a detailed description of the masonry artel of "Master Avdii" – a character in the chronicles about the construction of the castle in Kholm

Keywords: building materials; architectural details; stone; processing techniques; masonry tools

INTRODUCTION

The city of Kholm (modern Chełm on the territory of Poland) was founded by the King of Rus', Danylo Romanovych, in the middle of the 13th century. At first it was a small castle with a town at the foot, but later, realising the favourable location of this settlement, at the time when the Mongol army captured the Eastern part of the state, Danylo rebuilt and reinforced it, and turned it into a capital. Buildings of the 13th century have been preserved here only in the form of archaeological remains of the foundations and lower parts of the walls. The great historical significance of this town and the castle buildings led to the establishment in 2010 of an archaeological group at the Institute of Archaeology and Ethnology of the Polish Academy of Sciences to study the remains of the castle's building structure. The interdisciplinary team consisted of Polish and Ukrainian researchers who worked under the guidance of Professor A. Buko (2019). Archaeological research of the castle grounds revealed a system of fortifications, examined the remains of the main buildings, and provided rich material about the construction and technological solutions of objects. The various artefacts and information obtained by archaeological excavations will serve for scientific interpretations, understanding of everyday culture, reconstructions of castle objects, substantiating material about its construction stages and the nature of architecture. The analysis of the archaeological remains of buildings, the study of the technology of their construction and techniques for processing stone materials are important for answering the question of how a large metropolitan city could have emerged in a short time in the 13th century.

Papers on regional history often contain a presentation of material about stonemasonry regional traditions, but they mostly describe these traditions as lost and without a deeper explanation of the processes of stonemasonry (Gorbanenko *et al.*, 2021). The most common building material for the construction of representative buildings (cathedrals and castle complexes) in the 13th century on the territory of Kyivan Rus' was stone. Carefully crafted stone blocks were used to build plinths, corners of buildings, frames of window or door openings and cornices. Stone blocks were most often used to build the front part of the walls, but the interior was often filled with chipped or field stones (Gazda & Bevz, 2020). Operations of processing stone raw materials to produce construction and architectural and decorative blocks have a long history. Centuries of practice gave birth to the profession of a stonemason and led to the development of tools and traditional techniques for splitting, hewing, grinding, and carving stone material. Brick was used mainly in Lombardy, Southern France and Northern Germany, Denmark and the Netherlands. As a building material, brick began to spread in Eastern Europe only from the end of the 12th century, and in Rus'-Ukraine, chipped stone in combination with Byzantine plinth bricks were used for the construction of prestigious buildings. In Poland, the first brick buildings appeared in the early 13th century. Lime mortar was used in the masonry of walls to join stones or bricks. Residential and palace buildings, and the entire fortification complexes both in the Rus' and in Poland before the 13th century, were often built using wood and clay as the main building material. A similar tradition existed in neighbouring countries and Scandinavia (Wiewióra *et al.*, 2024).

Many years of archaeological research on the castle hill in Kholm revealed the destruction of stone and brick, but the scientific interpretation of the remains of the walls showed that the oldest authentic structures of the castle were built of natural and artificial stone. The most interesting result of archaeological discoveries was that the oldest buildings and structures (defensive walls, palace, church) were built from a local green glauconite stone (Buko, 2019). Its use in the construction of architectural buildings in the 13th century should be considered a unique construction phenomenon on the territory of Kyivan Rus' and Poland. Glauconite is a sedimentary rock with interesting aesthetic and technical qualities, unique among stone materials. This stone is found only in the vicinity of Kholm and occasionally in Western Volhynia (Gazda, 2017). Glauconite stone is relatively easy to process, which allowed the production of building blocks for walls and decorative elements – profiled glyphs of window and door frames and relief details with a relatively complex composition.

In addition to a large number of conventional rectangular hewn blocks used to build the walls, excavations on Vysoka Hirka (the name of the site where the castle was located) revealed a large number of carved architectural and decorative details made of glauconitite and limestone (Buko, 2019). The use of green and white stone materials testifies to the desire of King Danylo to create an architectural object decorated in the traditions of the Tuscan school (Gazda & Bevz, 2020). The Romanesque architectural forms used here also show the European orientation of the founder. The artistic carvings used to create the interior and exterior decoration of the palace and other buildings have analogues in the residences of the neighbouring countries of the Czech Republic, Hungary, and Poland (Jusupović, 2019; Fehér *et al.*, 2022).

The purpose of the study was to analyse all archaeologically discovered remains of walls and foundations, and separately found architectural details, to reveal construction technologies for the construction of buildings,

techniques for processing stone blocks and carving architectural details, which are used in the construction of castle objects at the first stage of construction.

MATERIALS AND METHODS

The research methodology was based on a detailed analysis of the remains of buildings and individual architectural details that were discovered as a result of more than 10 years of architectural and archaeological research of the castle. The study first highlighted the characteristics of natural stones used, then revealed the technology of laying foundations and walls; the next stage was devoted to the analysis of techniques for cutting, processing, and carving stone blocks; at the last stage, the technique of manufacturing architectural decor parts – profiled rods, cornices, columns, capitals, etc. – was analysed and reconstructed. Special attention was paid to deciphering the traces of processing stone surfaces with various types of tools. The information obtained helped to understand what tools masons worked with in the 13th century and reconstruct the technical equipment (set of tools) of the construction artel that worked at the castle of King Danylo.

Instrumental research methods were used only to analyse the microscopic structure of stones (Fig. 1). The research methodology was based on visual inspection of the remains of stone walls to identify the masonry technology, and subsequently on a visual inspection of stone building blocks, architectural details and elements to identify the techniques of their cutting and processing. Lists were compiled of those blocks that had detectable surface texture with traces of processing, including the lists of all architectural details found.

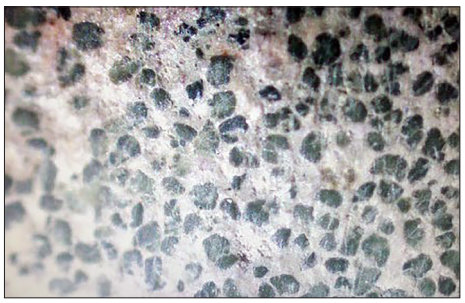


Figure 1. Surface of glauconite stone when magnified under a microscope
Source: photo by M. Bevz

Since the castle buildings were preserved only in archaeological form, the first surveys took place during archaeological excavations. This survey was carried out in the context of archaeological excavations "in situ", when foundations or walls were discovered archaeologically and documented. Visual inspection made it possible to identify those structural elements on which traces of finishing were well preserved. From these elements, a working list was formed for further surveys and recordings. The next stage of work was to photograph these analysed stone blocks or parts from the prepared list. If such blocks or parts were found not in the body of the wall structure, but in the collapse, they were removed, inventoried, and transferred for storage to the repository of the archaeological expedition. This helped to measure them later and take detailed photographs in the studio. Photographs of blocks and parts for surface texture analysis were taken in appropriate daylight or using artificial illumination of samples to reveal the texture. The results of photo recordings and measurements were part of the annual reports. Therefore, in addition to the authors' own photographs of the samples in the field, materials from descriptions and photographs from other reports were also used. Thus, the study analysed several dozen stone blocks and parts from different periods of the expedition, which lasted a total of 10 years. A special experimental part of the study was the selection of those samples of stone materials that belonged to the first phase of the construction of castle buildings. In this case, the authors relied on the interpretations of building substances by A. Buko (2019) and T. Dzieńkowski (2019). Papers by P. Rappoport (1954; 1994), which highlight stone details found during excavations in 1911, were used in the study only to compare the details found during new excavations with those found in the early 20th century. Publication of several photographs from the 1911 excavations by P. Rappoport showed these details in a low-quality image and on a small scale, which made it impossible to use this material for analysis.

The final part of the study was to investigate the processing methods of selected stone materials, blocks, or parts. First of all, the study of literary sources was carried out to identify the tools used by masons and construction artels in the Middle Ages. The scientific literature on this issue is not very extensive. There were no studies in Ukraine that would fully cover this issue, with the exception of isolated local studies (Ivanchyshen, 2017). Therefore, the authors used the synthesising studies by H.J. McKee (1973) and R. Jundrowsky (2015). Based on these studies, an orientation list of typical masonry tools characteristic of the period of the 13th century was compiled. The final stage of the study consisted in a detailed analysis and systematisation of traces on the surfaces of stones from the buildings of the castle of Danylo Romanovych. Comparison and interpretation of these traces, and their relation to the use of various types of tools, formed the final part of the study and allowed highlighting the picture of the "construction and instrumental support" for the building of King Danylo's castle in Kholm. Studies of structural glauconitite and limestone blocks were carried out both on the remains of walls "in situ" in archaeological excavations, and with specimens preserved in the museum collection of the Kholm archaeological expedition.

RESULTS

The walls of the structures at the first stage of the castle's development are made of stone using two technologies – "opus emplectum" and "opus quadratum". Most of the

sections of the walls were built using the first technology (Fig. 2). However, the glauconitite blocks at the corners of the perimeter defence wall and entrance gate were very carefully processed and perfectly matched, which allowed these objects to be made using the second technology.

Figure 2. Fragment of the wall of an unidentified castle building; a wall made of glauconitite was erected using the "opus emplectum" technology, excavations in 2015
Source: photo by M. Bevz

The buildings of the second stage of the castle's development were made of other materials and using different construction technologies and masonry techniques. In the foundations of these objects, the secondary use of high-quality architectural details and rectangular blocks of glauconitite is documented. That is, the second construction period came after some kind of disaster, when previous buildings were destroyed and their material was reused in new buildings. Refusal to use glauconite stone at the second stage of construction can also be a consequence of the complete depletion of resources of this raw material or a negative experience of using this stone, which turned out to be unstable to atmospheric influences (Gazda, 2017) or exposure to high temperatures in case of fire.

The wall construction technology "opus emplectum" involves careful masonry of the front parts of the walls from rectangular hewn blocks (Fig. 3). But the interior of the walls is filled with broken stone of irregular shapes and filled ordinarily with mortar. This type of wall is built quite quickly and has sufficient strength, but it requires a fairly large amount of lime mortar of very good quality. Glauconitite blocks, well-matched in height in a horizontal string of rows, were used in the cladding parts of the walls of King Danylo's residence, both internal and external.

The stone blocks had different sizes, dominated by three types: 40×25×20 (length x width x height), 33×34×23, or 37×23×22. A special feature of the walls was that the average height of blocks in one row of walls was always the same (the principle of Romanesque architecture), which ranged from 20 to 23 cm (Fig. 4). These are rather small block sizes, so a logical question arises – what is the reason for such dimensions. This height of the blocks may correspond to the approximate thickness of the horizontal productive formation in the quarry. In particular, it is known about a glauconite cloak over the continental chalk layer in the castle section of Kholm (Gazda & Bevz, 2020). That is, the building material was even at hand at the construction site of the residence facilities.

Figure 3. Fragment of the wall cornerstone made of rectangular hewn blocks of glauconitite
Notes: traces of various hewing methods can be seen on the surfaces of the blocks
Source: photo by S. Gołub (2018)

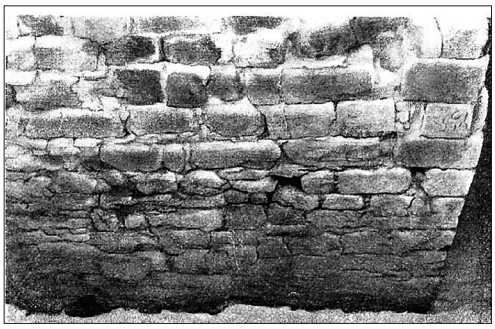


Figure 4. Photo of the North-Western part of the castle wall; excavations by P. Pokryshkin, 1912
Notes: two ways of building a wall can be easily distinguished: 1 – the lower layer is conscientiously and efficiently constructed, 2 – the upper part (the top two rows) is constructed not as carefully. There are also two types of stone blocks – a) of a clear cubic shape and b) when only the front surface and the bottom and top planes of the blocks are quilted evenly, and the two side planes have a broken irregular shape
Source: P. Rappoport (1954)

The walls in the Southern part of the castle hill have been preserved to a height of 1.5-2.0 m. The outer two-metre-thick wall is made of stone in such a way that the sole of the wall in cross-section is not horizontal, but stepped down the slope. The difference between the internal and external levels of the lower part of the wall can be more than 1 m. Therefore, the external preserved part of the wall has a height of more than 3 m. An important result of recent research was also that the wall was not built strictly vertically, but with a slope towards the middle on the outside (Buko, 2019). White and green stone paving on lime mortar was found on the inside of the wall. Research in 1911 revealed an underlying layer of rubble stone filled with lime mortar under the paving. Such a design may

indicate that it was not a paving of the yard, but a floor structure. An additional argument for this interpretation is the information that lime mortar also penetrated the wall thickness (Rappoport, 1954).

Outside the castle wall, 3 m below the hillside, another glauconitite wall was discovered in the Southern part of the hill, which consists of several rows of large stones. It was also mentioned and described in general terms by Pokryshkin. He interpreted it as the former foundation of the mountainside (Rappoport, 1954). This interpretation cannot be accepted due to the fragmentation of the studied area. So far, there is no confirmation of the existence of this "foundation" around the entire perimeter of the mountain. In the South-Eastern part of the castle, behind a two-metre defensive wall, the remains of wooden log structures were found (well below the base of the two-metre wall). It is this type of structure that was most often used in medieval Rus' for the construction of ramparts and for strengthening artificial platforms of fortification objects. Most likely, these remains are traces of crates that served as the binding structure of the hillside and may have encircled the entire hill. However, there is also the assumption of A. Buko (2019) that it could have been the wooden remains of a shaft built in the later, second period of the castle's functioning.

Excavations in 1911-1912 revealed the remains of a structure made of glauconite stone, which Pokryshkin called a "tower or well" (Rappoport, 1954). New research on the object proved that it was built using the "opus emplectum" technology. Along the perimeter, the foundation walls of the building had an approximate shape of a square measuring 5×5 m and a round inner part with a diameter of 2 m. The walls are made of not very carefully hewn blocks and slabs of glyconite on a white lime mortar with a small sand content. The repair section of the exterior of the walls using Sarmatian sandstone was traced (Dziekowski, 2019). A similar tower in the plan of the 13th century was preserved in Stolpie near the Kholm. Its dimensions in the plan are also 5×5 m and the diameter of the inner part is 3 m. This object was examined in detail by A. Buko (2016). Its walls, however, are built of quartz sandstone, and not of glauconitite.

An important addition to the discovered technology for the construction of walls "opus emplectum" was the opening in the Northern part of the castle hill. The remains of the so-called building "D" demonstrated the combination of a stone wall with wooden reinforcement. The stone structure in the lower part is made of glauconite stone on a light cream mortar. The walls of the building in the lower part were built with powerful wooden beams measuring 20×35 cm embedded in the body of the wall. The bars were laid in the middle along the axis of the wall at the same height and probably intersected with the cuttings in the corners (Fig. 5). The wall thickness averaged 80 cm. Thus, another innovative technique (reinforcement of the wall structure) can be noted in the castle construction in Kholm. Perhaps this technique was used in other buildings of the residence, but their preservation only in the foundation form does not allow confirming this with sufficient confidence.

Figure 5. Fragment of the wall (OBD) of the stone wall of building "D", built of glauconitite blocks in the "opus emplectum" technique and reinforced with wooden beams
Notes: the photo shows a hole in the wall body left by a wooden beam. The property is located in the Northern part of castle hill
Source: photo by M. Bevz

Hewn blocks of glauconitite for wall construction and carved architectural details that appear as archaeological relics on Vysoka Hirka demonstrate examples of extremely high structural and artistic performance. The quality of the hewing of conventional wall blocks is very thorough and precise. Some of the best-preserved authentic wall fragments and carved details show perfectly hewn and even smoothed flat surfaces of blocks or profiled elements of architectural forms (Gazda & Bevz, 2020).

Compared to other types of sandstone, glauconitite is characterised by relatively soft grains with similar binding properties. Grains, apart from soft fragments and bioclasts of Cretaceous rocks, are 80% composed of the clay mineral glauconite, formed into spherical shapes (Fig. 1), with a characteristic aggregate internal structure (Gazda & Bevz, 2020). When hewing or cutting glauconitite blocks or parts, its structure makes it easy to separate the bonds between the grains, rather than, as is the case with quartz sandstones, breaking them by force in the processing plane. As a result, this material behaves more plastically, but with strength parameters close to most sandstones. This structure has an important aspect for research – the surfaces of the 13th-century Kholm glyconite blocks and details show clearly visible traces of processing. In some cases, these traces are traceologically consistent with the stone tools found in the excavations (Gołub, 2018).

The presence of carved architectural details and fragments of artistic stone decoration in the castle ruins can be a clear confirmation of the records of the Halych-Volhynian Cronicle about the skilled craftsman Avdii, who worked and carved stone for the artistic decoration of buildings (Makhnovec, 1989). The repeatability of the masonry methods and techniques of processing the building stone used in the construction of the walls in the form of well-carved parallelepiped blocks may be evidence of the work of a highly professional building and masonry artel. This artel was well acquainted with the technologies of building

buildings in the Romanesque architectural tradition (Gazda & Bevz, 2020).

Analysis of the building and decorative elements suggests that the Kholm craftsmen used a standard scheme for the execution of architectural details in stone. At the first stage, the quarry chipped off the rock in layers of more or less standard height stone blocks of close to rectangular shapes. For the first operation, the quarry used rough hammers and baffles. Visual analysis of stone glauconitite blocks revealed the use of wide toothed baffles. Such a tool was driven with a hammer along a drawn line on the surface in two places, tearing off the stone mass of a more or less regular shape. Such a stone block should have been chipped off due to the thickness of the productive layer of stone. According to archaeological studies of Vysoka Hirka, the thickness of the glyconite layer there was 60-100 cm (Gazda, 2017). It was possible to break off part of it in a vertical chip, breaking off part in the desired direction. Traces of using this chipping method were found on several blocks (Fig. 6). Subsequently, the block obtained by chipping off a rough, often irregular shape was pressed to the desired shape on the construction site. To obtain blocks of the desired size and rectangular shape, their surfaces were worked out in more detail by cutting. In particular, the front surfaces of many blocks were hewn with a 2-centimetre flat mason's hammer (Fig. 5). The photo shows clear traces of such a tool – diagonal stripes on the left side. The surface of this block also shows traces of light adjustment with a trowel or a toothed mason's hammer. This last operation is indicated by small vertical stripes in certain places on the surface.

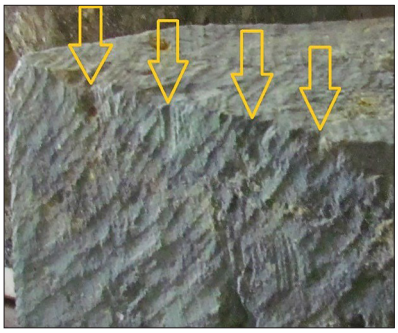


Figure 6. Traces of block splitting with a four-tooth baffle
Source: photo by M. Bevz

Getting smooth surfaces of the stone block required chipping the excess mass of stone around the entire perimeter of the block. Excess parts of the stone were chipped in the right places, first with comb cleavers, then with ax-hammers or toothax-hammers and mason's hammers (also toothed or flat). No traces of sawing stones were found, so the use of saws to form glauconitite blocks was probably not practiced. On the surfaces of the blocks, there are sometimes traces of hewing with a wider hammer with strips of 40-50 mm (a toothax-hammer is a tool similar to a small double-sided axe). There are examples when the excess protrusion formed after breaking off blocks at the first stage was roughly removed with a comb chipper, and then pressed down with a flat one (Fig. 7) or the toothed end of the mason's hammer. This final phase of finishing with a flat or toothed mason's hammer or toothax-hammer is carried out until the surfaces are smooth.

Figure 7. Image of two stages of surface treatment of a stone block
Source: photo by M. Bevz

A flat plane of the walls of blocks or architectural details was obtained in stages: at the first stage, pointed cleavers were used for glauconitite or limestone stone – for the primary removal of stone mass (Fig. 7, bottom of the block), and at the second stage, hewing with a flat or toothax-hammer or mason's hammer with a width of approximately 40 mm was used (Fig. 7, top of the block). The photo clearly shows these two phases of surface treatment of the block, left in the form of traces: at the bottom of the block – a roughly hewn plane with traces from the comb chipper; at the top – a plane smoothly hewn in the second phase with a small flat mason's hammer.

A special invention of the Kholm stonemasons is the production of a certain number of blocks "with a hook" (Fig. 8). Such a block played an important role for more perfect binding of stones in masonry. Especially useful was its use in the corner parts of the walls of buildings. It provided reliable strength of the wall corner, which has always been a weak point in masonry technology when conventional rectangular blocks were used.

Figure 8. An example of a profiled glauconitite block "with a hook" – a protrusion in the rear inner part for better binding and "hooking" the block in the wall
Source: photo by M. Bevz

This technique testifies to the high professionalism of the masons. In Romanesque building practice, it is not very common to find a technique where corner blocks have a protrusion in the back along the entire height for better fastening and "hooking" the block into the wall thickness. This formal decision is very important for the masons who build the structure. The fact of its use indicates a well-thought-out masonry technology and purposeful management of all stages of construction of structures on Velyka Hirka during the construction of the Danylo's residence (Fig. 9). The products of the stone workshop and the likely guidance of the carver Avdii (Kotliar, 2002) over the production of decorative elements prove that they were not only artistically well executed, but also competently designed technologically for their further use in the construction of walls and as decorative elements of buildings.

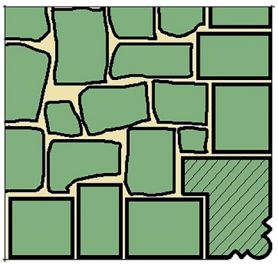


Figure 9. Application of a stone block "with a hook" in the construction of the cornerstone of the wall of the Kholm castle
Source: developed by M. Bevz

The analysis materials showed the use of several methods of cutting stone and the use of several types of tools. Based on the results of the analysis of stone building material, it can be confirmed that three types of hewn blocks were used in the castle buildings. The first was used for laying foundations and exterior walls (with a rougher wall texture), the second – for interior walls with a well-patterned, flat surface of the block faces, and the third – for interior or exterior walls with profiled elements or carved decor. The third type of blocks required the most careful execution, more operations and tools. The blocks of the third type were even polished. A separate group consists of delicately carved elements made of white limestone – a fragment of the capital with an acanthus leaf and a block of the faceted nervure base. Even in the first type of blocks for wall construction, the face and side joint surfaces were very carefully made with flat planes. Most often, masons at the Kholm castle used a double-sided mason's hammer for trimming building blocks – flat pointed at one end and toothed at the other, or flat pointed on both sides. During archaeological research of the castle, two such tools of different sizes were found (Fig. 10).

In the walls of castle buildings, there are often blocks with traces of hewing with a mason's hammer with a single sharp tooth (Fig. 11). This trace is obtained from the most common type of mason's hammer – when this tool has a sharp tooth at one end and a flat blade (or hammer) at the other. Sometimes such an instrument is called a kilof (McKee, 1973). In some regions of Ukraine, mason's hammer is also known as "pickaxe" (Ivanchyshen, 2017). There are a number of blocks where the sharp part of such a tool was used to roughly chisel off the excess mass of stone and then to level the end and face surfaces of the block with the flat part.

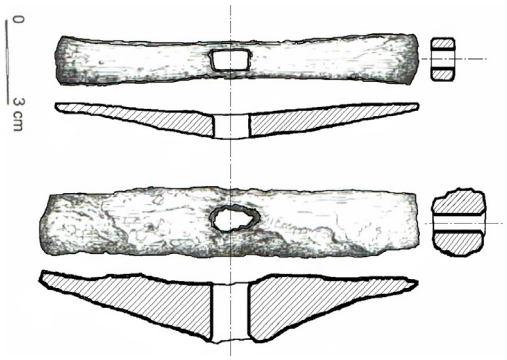


Figure 10. Illustrations of two tools: a narrower and a wider straight mason's hammer with two straight edges, found in excavations in 2013 and 2016
Source: developed by E. Hander and M. Bevz

Figure 11. Example of cutting and processing a glauconitite block
Notes: the side surface has traces of hewing (in different directions) with a sharp-edged mason's hammer; the front surface is perfectly flat and polished. The cornerstones of the block are levelled with a fine-toothed chisel or skarpel to a width of 15 mm
Source: photo by M. Bevz

One interesting technological pattern is observed: the front surfaces of blocks hewn with a mason's hammer or chisel, as a rule, have a diagonal direction of hewing in relation to the rectangular surface. It can be assumed that the use of this technique was conditioned by the desire not to cut the edge of the stone surface at right angles. When cutting perpendicular to the edge of the stone block, it would be more difficult to get a straight line of the cornerstone edge. Such diagonal cutting resulted in the final flat "working" surface of the block. Small traces of diagonal hewing with a mason's hammer are found on many glauconitite blocks (Figs. 6, 11).

The use of certain tools by the construction workforce is supported by archaeological finds of the tools themselves. The metal parts of two more masonry tools were found in the Southern part of the castle during archaeological research in 2011 and 2016 (Fig. 12). These were two different types of chisels and two types of mason's hammers with flat ends. The use of each of these two tools provided a different surface texture. When processing the surface of the stone with a chisel, the bricklayer also used a wooden hammer (mallet). The chisels always leave long, very distinct, even-width grooves on the surface of the stone that correspond to the width of the blade.

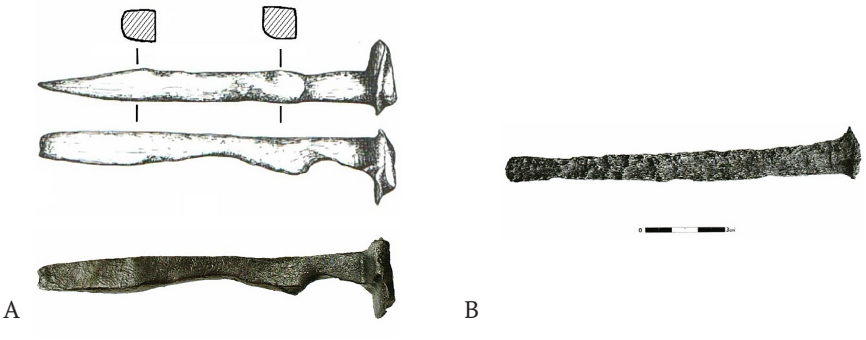


Figure 12. Photos of two types of iron chisels found during archaeological excavations in Kholm
Notes: A – in 2011 in the Southern part of castle hill; B – during the excavations of the Church of the Virgin Mary in 2013
Source: photo by G. Zablocki

Cutting with a mason's hammer is characterised by short traces of "cleaves". The width of the hewing edge depended on the width of the blade. Two widths of the hews were recorded: 20 mm and 30 mm, which corresponds to the tools found in the excavations. On the walls of the stone blocks, traces of such hewing were usually in the form of parallel rows (Fig. 13).

Figure 13. External surface of the wall block made of glauconitite, hewn with a flat mason's hammer
Notes: thick traces of short hews are visible
Source: photo by M. Bevz

Sometimes, among the museified glauconitite blocks in Kholm, there are traces of hewing with a chisel rather than a mason's hammer. In this case, the notch on the body of the stone will be long rather than short. When using the chisel, stonemasons struck them with a wooden mallet (a hammer with a round head) (Discover the secrets..., 2023). The mallet with such cutting was a convenient light tool that allowed not to hit, but as if to push the chisel, extending its course. As a result of this operation, the use of a chisel tended to produce longer, parallel "hew marks" that ran in the same direction on the surface of the block (Fig. 14).

Figure 14. Example of hewing the side surface of a glauconitite block with a flat chisel with a blade width of 12-15 mm in two directions
Source: photo by M. Bevz

Hill craftsmen also used toothed chisels of different widths and sizes of teeth. All glauconitite or white stone blocks, which were elements of architectural decoration, had perfectly straightened block faces or fractures in their shapes. This kind of preload has characteristic traces-stripes from the use of a fine-toothed chisel (Figs. 8, 11, 15).

It should be noted that various types of mason's hammers have been recorded for cutting blocks. In particular, smooth surfaces of blocks were obtained using a mason's hammer with a three-pronged blade (Figs. 16, 17). Judging by the tracks, it was a tool with a sharp toothed blade with a tooth pitch of 7-6-5 mm. The interval between the teeth was 1 mm. Traces of this type of hewn surface have been found on many glauconitite blocks in the Southern part of the castle. As noted, traces of cutting with a mason's hammer are easy to identify, since they have the character of short cutting-notches. Depending on the type of blade of

the mason's hammer – toothed or flat, the corresponding profiles of the ditches appear on the surface of the stone as traces of cutting.

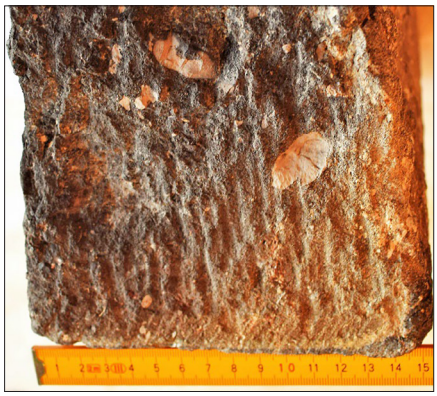


Figure 15. An example of a surface hewing with a fine-toothed comb chipper (clearly parallel ditches of equal depth)
Notes: the bottom edge of the block is trimmed with a fine-toothed chisel – 15 mm wide strip
Source: photo by M. Bevz

Figure 16. Surface of a glauconitite block with traces of cutting with a three-pronged flat mason's hammer
Notes: repeated marks of the three teeth of the tool are specially marked, indicating the direction and density of chiselling
Source: developed by M. Bevz

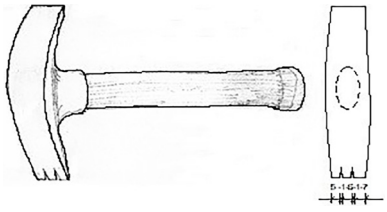


Figure 17. Hypothetical drawing of a three-pronged flat mason's hammer used by a stonemason's artel in the 13th century
Notes: dimensions of the toothed blade: 5-1-6-1-7 mm
Source: developed by M. Bevz

The marks recorded in Figures 15 and 16 from cutting with a toothed mason's hammer indicate the use of a 3 cm wide blade. The blade of this tool is asymmetrical – the teeth are different in width (Fig. 17). The direction of hewing is diagonal to the rectangle of the block surface. The edges of the surface are also trimmed with a toothed chisel in a beveled direction towards the edge of the block. This has its own explanation – it would be difficult to get a flat corner of the block with the perpendicular movement of the chisel. If the chisel is used to cut the edge at an angle, the part of the chisel always remains on the surface of the block, allowing for continuous cutting movements by moving the tool along the edge. The surface of this block (Fig. 16) also demonstrates the fact that when cutting with a mason's hammer, the corner of the block did not turn out to be of high quality. This effect of using a mason's hammer differs from working with a chisel. With the help of a chisel, it was possible to delicately press the cornerstones of the block with diagonal movements. This could even be done manually, without using a mallet. In the same illustration, a closer look reveals that the right and upper edges of the block surface are not hewn with a mason's hammer, but are trimmed with a delicately toothed chisel.

On the surfaces of individual glauconitite blocks, a different size of mason's pick was also used (Fig. 18). It has a wider blade of 4 cm and more worn rounded three teeth. Traces of hewing with this wider-toothed mason's hammer were recorded on glauconitite blocks that may belong to the shrine of St. John Chrysostom, the castle chapel of King Danylo Romanovych, whose construction in majestic, perfect forms was a special intention of the founder (Voytovych, 2016). These blocks, as proven by research, are decorative elements of the entrance portal to the shrine (Bevz, 2019). The front sides of these blocks have a smooth polished character, and only the surfaces of the sole and upper of the block have a smooth surface hewn with a mason's pick. These surfaces connected the blocks to each with mortar, creating a complete architectural form of the portal. This shows a very skilful hewing of the surfaces with a toothed mason's hammer, which were later to create an invisible seam when the blocks were joined. The resulting horizontal surfaces of the blocks turned out to be perfectly smooth and convenient for connecting to each other through a thin seam of mortar.

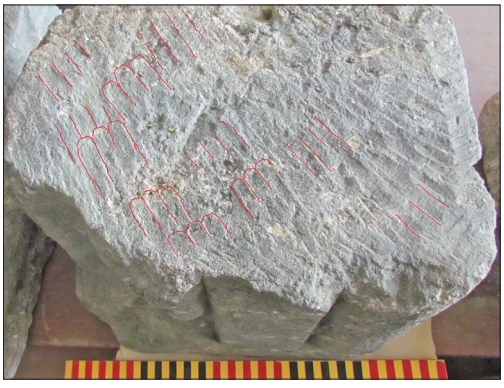


Figure 18. Lower profiled block of the left portal
Notes: traces of hewing with a trident claw with a three-pronged mason's hammer with a blade width of 4 cm on the upper plane of the profiled glauconitite block
Source: processing and photo by M. Bevz

To obtain smooth face surfaces in stone blocks, which were made as decorative elements, Kholm craftsmen used various techniques of their final finishing. In particular, grinding or surface treatment with a chisel or scraping was used to finish the hewn surface. For polishing, stonemasons usually used blocks of hard stone with a grid of notches. Another method of obtaining a flat surface was to use wide flat chisels and skarpels. The essence of this method was to treat the surface with a dense network of perpendicular impacts with a sharp flat skarpel blade or chisel. As a result, it was possible to remove uneven bumpy areas from the surface of the stone and get a densely split flat surface, with the appropriate texture. The textured pattern of the surface depended on the master's plan. It could give it the character of thick parallel notches (Fig. 19) or a grid of perpendicular lines, etc. This type of surface was made in those blocks that were used in the interiors of the building or for decorative elements on the facades.

Figure 19. Rounded surface of the half-column with the texture of a vertical grooved character, obtained by thick blows with skarpel perpendicular to the surface of the part
Source: photo by M. Bevz

Two types of flat iron chisels were found in archaeological excavations at Kholm castle (Fig. 12). They differ only in the shape of the head. Their working blades are similar and have a width of about 2 cm. Instead, the use of notched chisels is only confirmed in the form of specific marks on stone blocks. That is, the use of both flat and toothed chisels was common. As a rule, they were used in the manufacture of profiled and carved parts. But their use was also recorded for levelling the front surface in building wall blocks. On the front walls of blocks and architectural elements from castle buildings, traces of jagged chisels are most often found. The use of such toothed chisels of two types was recorded – with small thick teeth on the blade, as well as with three wider teeth (the so-called "trayanka").

At Kholm castle, operations were also performed to cut flat surfaces of stone blocks using skarpels – a tool similar to a chisel, but with a wider blade. Skarpels, like chisels, are found with a flat or toothed blade. The use of both flat and toothed skarpels has been confirmed. Flat ones were often used to cut off excess parts of the block, for example, if necessary, to get grooves-fluting or the shape of rectangular profiles. An interesting feature is the use of skarpels to create a smooth but textured surface of the block. In particular, in this way, skarpels were used to produce smooth surfaces, and then to give the texture a grooved character by thick strokes of skarpels perpendicular to the surface on the front part. The study showed that even the surfaces of rounded half-columns were treated in this way. An example of this finishing technique is clearly visible on the body of a half-column in the corner blocks of door frames (Fig. 20). The plane aligned with the toothed wide skarpel is also fixed on the upper surface of the profiled glauconitite block with the guilloche (Fig. 21).

Figure 20. Marking with a spike or nail of a modular grid (guilloche) on the upper surface of a profiled glauconitite block
Notes: the engraved lines are drawn in yellow. The centre trace from the compass is also marked with a cross when measuring the half-column
Source: processing and photo by M. Bevz

Figure 21. Reconstruction of the scheme of using compasses and a ruler for measuring and constructing profiling on the following blocks based on the use of a template – a modular drawing on stone with guilloche
Source: processing and photo by M. Bevz

A very specific tool was also used in Kholm to create smooth face surfaces on glauconitite and limestone blocks – a drawknife. The drawknife consists of a wooden handle with several fine-toothed steel blades attached to it. Two types of such tools are known: the first, when metal-toothed plates are embedded in thick parallel strips in the slots of a wooden bar; the second, when a specially

made metal stretchable strip is embedded in the bar in two directions. Often, the toothed blades of fine saws were used to make drawknife. This tool was used to perform the final alignment of the block surface. The toothed blades left shallow parallel small grooves on the body of the stone (Fig. 22).

Figure 22. Example of final treatment of the front surface of a glauconitite block
Notes: the surface of the block is perfectly flat, which indicates the use of a drawknife; small parallel lines from the teeth also indicate the use of this tool; after hewing, the edges of the block are delicately cut and levelled with a fine-toothed skarpel or chisel – a strip along three edges 10-15 mm wide
Source: photo by M. Bevz

The stonemasons used not only percussion tools, such as toothax-hammers, mason's hammers, and partially skarpels. The initial important part of the process of making decorative elements was to apply drawings on stone blocks for their subsequent processing to obtain profiled or other, in particular, carved parts. A compass and a so-called spike (a sharp pencil-shaped metal tool) were used to draw the required profiles on the stone. Shpichak had a dual function: it served to make drawings, lines, profiles on the surface, but it also served to drive a stone into the body, if necessary, break off part of it, or to create a depression (McKee, 1973). For example, such depressions and protrusions were specially knocked out on the two surfaces with which the blocks were joined, for better adhesion. If it is necessary to obtain a profiled side of the block or some carved contour, the desired contour was applied to the pre-treated flat surface of the block with a sharp metal "spike". On several glauconitite blocks, lines were found applied to the levelled smooth surface-marks for removing unnecessary parts and marking places where blocks can be bound.

On one of the blocks there is a unique pattern cut out with a spike or nail. A template (guilloche) was drawn on the wide surface of the block for drawing and carving subsequent decorative blocks of this type. In this case, this refers to a type of block with an angular carved half-column and a double strip of fluting (Figs. 20, 21). A separate illustration shows a reconstruction of the measurement scheme and constructions using compasses and a ruler of the process of finding and drawing the profile of a half-column and fluting. After such a drawing of the desired contour on the upper surface of the block, the excess part of the stone was cut off. It can be concluded that the guilloche block was made first, and later served as a reference for measuring and transferring the circuit to subsequent blocks of such profiling. In total, more than 10 corner blocks with such profiled decor were found in excavations in recent years and in excavations from 1911-1912. Rectangular profiling of blocks made of arched or other curved elements was performed with chisels (Fig. 23).

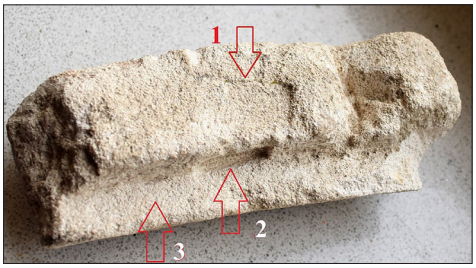


Figure 23. Fragment of a white stone curved profiled part with traces of surface treatment with a chiselk
Notes: 1 – trace from the use of a flat chisel with a width of 20 mm for horizontal chipping of the surface; 2 – trace from a flat chisel with a width of 20 mm and a thickness of 1.5 mm for profiling, cutting off part of the stone; 3 – very thin diagonal traces from removing part of the stone with a fine-toothed chisel or skarpel to obtain a flat surface and a rectangular profile of the part
Source: photo and designation by M. Bevz

The rounded shapes of architectural details and carved elements of a more complex nature were polished with a fine-grained rounded wheel or a specially made stencil made of harder stone. Although it should not be excluded that a small thick notch with vertical stripes may indicate the use of skarpel for chipping excess parts of the stone mass. The surface of a vertical half-column with a carved grid of furrow marks forms a perfectly rounded shape with small regular tool marks (Fig. 21). Perhaps, to get such a correct shape, masons also used a convex template, which constantly checked the correctness of the hewn shape of the half-column. For carving rounded surfaces, rounded chisels were used – the curve chisel (Fig. 24). Curve chisel, like other chisels, could be of different sizes (widths) and different curvatures. The front surfaces of the blocks could be sanded. This is demonstrated by the front, very flat polished surface of the block found in an excavation site in the Northern part of Kholm. The fact that the grinding operation itself took place is indicated by curved furrows from circular movements on the surface (Fig. 24).

Analysis of profiled stone parts shows that the edges-cornerstones of semicircular or other convex shapes in architectural profiles were finally delicately cut at an angle of 45 degrees with a fine-toothed chisel (Figs. 20, 21). This pattern of cutting the cornerstone was performed by a special operation, when the chisel was placed perpendicular to the line of the cornerstone, but moved to cut at an angle of 45 degrees. After such a delicate cutting of the corner of the block, its sides were pressed in accordance with the level of the strip of the corner. Over time, their surfaces could also

be sanded. For carving more complex architectural forms, various widths of chisels, skarpels, curve chisels, and drills were used.

Figure 24. Example of a glauconitite block with angular vertical half-columns and fluting
Notes: two shallow fluting grooves were made according to the prepared pattern by cutting with a wide skarpel and then levelling with a fine-toothed chisel with the movement of its blade at an angle of 45 degrees. The body of the half-column has vertical traces from sanding or delicate processing with skarpel. The front surface of the block is also smoothly sanded in different directions
Source: photo by M. Bevz

In addition to a large number of ordinary rectangular wall hewn blocks, excavations on Vysoka Hirka revealed a certain number of architectural details or fragments made of glauconitite and limestone, which had a carved decor. An example of a highly artistic design of such a detail is a fragment of a limestone stone capital (Fig. 25). The part is polished and very delicately carved. The nature of the carving and style of acanthus leaves are very similar to the products of the Galician school (Gazda & Bevz, 2020). The unique feature of this piece is the use of intarsia – glauconitite "eyes" are inserted in the drilled acanthus curls.

Figure 25. Fragment of a carved capital corner with an acanthus leaf
Source: photo by M. Bevz

The summary Table 1 presents the results of a comparative analysis of the use of various tools and, accordingly, different techniques for cutting and processing structural stone blocks or architectural details. The results demonstrate the use of traditional medieval tools and techniques. For a better understanding of the use of a particular stone cutting technique, along with a photo of the stone surface, an image of the tool that was used for the technological operation is presented.

Table 1. Techniques for processing and carving stone in buildings of the 13th century on Vysoka Hirka in Kholm with identification of appropriate tools

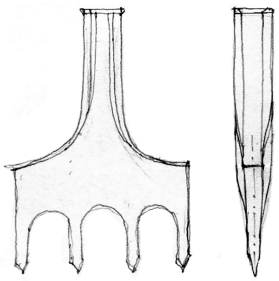
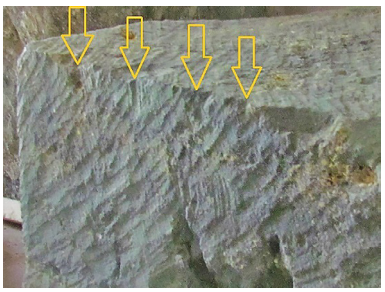
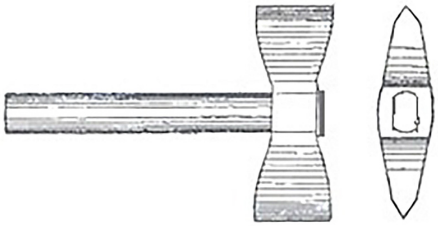
No.	Tools, name	Photo of the treated stone surface
1	 Baffle	
2	 Ax-hammer	

Table 1. Continued

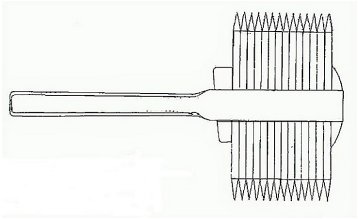
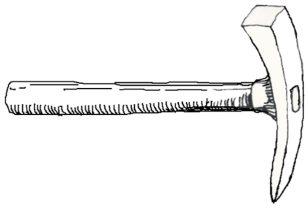
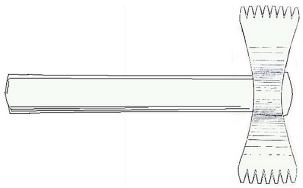
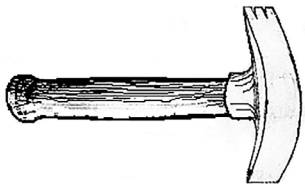
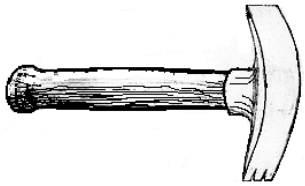
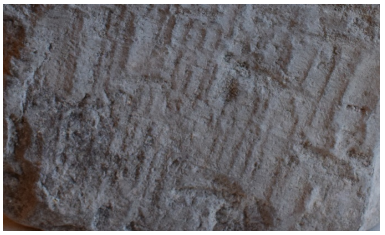
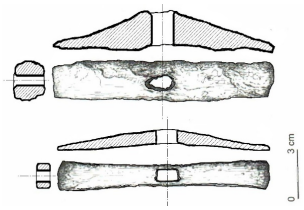
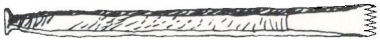
No.	Tools, name	Photo of the treated stone surface
3	 Crandall hammer	
4	 Mason's pick with hammer and point end	
5	 Toothax-hammer (made with teeth of the desired size – small or large)	
6	 Mason's hammer with combined blades – flat and toothed (hewing with the flat side)	
7	 Mason's hammer with combined blades – flat and toothed (hewing with the toothed side)	
8	 Mason's hammer with two flat edges (the edges of the blade are slightly rounded due to grinding)	
9	 Fine tooth chisel (alignment of block edges)	

Table 1. Continued

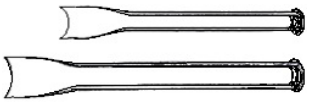
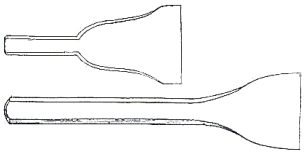
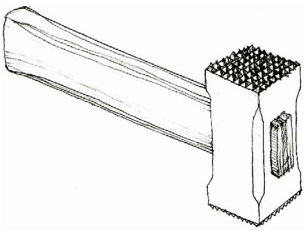
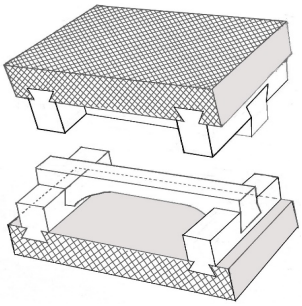
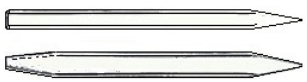
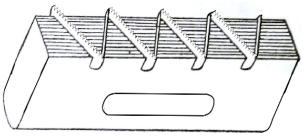
No.	Tools, name	Photo of the treated stone surface
10	 Trident tooth chisel	
11	 13th century narrow chisels found on Vysoka Hirka	
12	 Curve chisel	
13	 Skarpel	
14		
15	 Grinding stone	
16	 Spikes (thin and coarse)	

Table 1. Continued

No.	Tools, name	Photo of the treated stone surface
17	 Drawknife (adze)	

Source: developed by M. Bevz

The results of the study do not provide grounds for accurate dating of the processing methods used (since the blocks could be reused and further processed). However, no other methods of stone processing were found, even in cases where repeated use of blocks was suspected. Most carved and hewn limestone and glauconitite blocks or parts, according to their formal characteristics, belong to the same construction period. Although they have been found in various excavations in different parts of the Vysoka Hirka, the similarity of their processing is beyond doubt. The results of the study, on the one hand, demonstrate the complete tools of the construction artel and, on the other, show the relative conservatism of the development of construction technologies in the 13th century in Kholm. This is evidenced by the absence of traces of the use of saws and mechanised operations.

DISCUSSION

The list of researchers who have considered the architectural and construction aspects of King Danylo's castle in Kholm is very narrow. These are usually participants of an architectural and archaeological expedition working on Vysoka Hirka since 2010. All of them are listed above. Therefore, their assessment of the accuracy of interpretations should be relied upon. The discussion element of the presented study is the correct interpretation of: a) technologies for building walls; b) techniques for processing building blocks and architectural decorative details. If the discussion on the first issue is hardly possible, since the nature of the two types of masonry is clearly recorded in the reports, documents, and drawings of the expedition and is beyond doubt, then on the second issue (interpretation of the tools for cutting blocks and parts by the masonry artel), hypotheses are expressed for the first time and a discussion and critical remarks can be expected.

Regarding the first aspect of the study – technologies for building walls, it should be noted that the first researcher who highlighted this issue was P. Rappaport (1954). Based on the analysis of reports and notes of archaeological research by P. Pokryshkin since 1912, P. Rappaport (1954) first revealed the technological features of the construction of walls in the castle of Danylo Romanovych. However, its descriptions are directed only to objects in the Southern part of Vysoka Hirka. Repeated excavations in 2017-2020 in this part of the castle fully confirmed the results of the first expedition (Buko, 2019). Excavations revealed a rectangle of walls in the Southern part of Kholm (measuring 33×22.5 m), surrounded by a defensive wall about 2 m thick. The wall is made of stone in the "opus emplectum" technology. Pokryshkin's notes indicated that the wall was dominated by green glauconitite and white limestone. The yellowish and reddish stones mentioned in the notes turned out to be glauconitite blocks that changed colour due to high temperature (the fire of 1256) (Gazda, 2017). The outer face of the wall is made up of larger stones, while the inner face is made up of smaller stones. On the corners, an exclusively green stone was used, in the form of better-processed, rectangular blocks. Occasionally, there are 20×25 cm nests in the wall. P. Rappaport (1954) interpreted them as remnants of scaffolding. The correctness of this interpretation should be verified by additional studies. Nests of this size were probably intended not for scaffolding, but for structures. Horizontal rows and layers of stone in ants were carefully stacked from blocks of a certain equal height in each row, but the rules for tying blocks together were not strictly observed (Dzieńkowski & Gołub, 2018). An important and interesting conclusion from the research of 1910-1912 is contained in the notebooks of P. Pokryshkin, where he notes that the outer side of the wall was probably plastered or had a wide grout: there are traces of grey lime mortar on the wall, but the mortar in the masonry and joints is slightly whiter (Rappaport, 1954). The researcher also did not rule out possible lime painting of the walls.

Research of the expedition led by A. Buko (2019) in 2010-2018, in addition to re-opening the remains of the castle in the Southern part, also carried out several excavations in the Northern part of Vysoka Hirka. A total of 32 excavations were completed. Regarding the second aspect of the study – techniques for processing building blocks and architectural decorative details – this issue has been ignored by Kholm researchers until recently. Published materials from P. Pokryshkin's research mention about 30 architectural details found, but only a few details were described, paying attention only to their shape and size. That is, they are not put into scientific circulation, and the published materials do not cover the issues of their manufacturing technology. The results of new research under the guidance of A. Buko (2019) allow supplementing this collection with new carved elements of approximately the same number, but they also did not become the subject of

a separate publication. The need to generalise and systematise the results of long-term research of the Kholm residence in the construction and technological aspect was emphasised by S. Gołub (2018). In the study of stone processing techniques, the analysis covers only the latest architectural elements found (from excavations in 2010-2018), so to a certain extent this study is not complete and it is expected to be supplemented with more details. However, even in this format, the technical means and technological features of the local Kholm stonemasonry school are fully described.

For the first time in the scientific literature on construction in 13th-century Ukraine-Rus', the technological and technical aspects of the process of constructing a stone building are described in detail: materials, stone processing techniques, tools used for this purpose, features of masonry, methods of making decorative elements, and various types of decorative surfaces in stone blocks. Although previous researchers declared that they had covered this topic, they merely listed the types of stone and stated that manual methods of processing were used without disclosing detailed characteristics of the types of work and tools. Such an example is the study by P. Rappoport (1994). In addition, the above study incorrectly classified the buildings of Kyivan Rus' as Russian. Another part of the researchers (Jundrowsky, 2015) tried to describe the development of the stonemason craft during a certain historical period. These studies contain lists of typical tools that were used in certain historical periods, but often there is no specific data on the relationship between the construction of a building and the nature of masonry operations, their technological sequence. Especially when it comes to the older medieval period. There are also papers containing the analysis of the stone material itself, but without conclusions about its processing technologies (Hutzuliak & Shevchenko, 2016). As a result, the analysis presented in this study is implemented, since the Kholm castle is in the form of an archaeological ruin, as if in a "disassembled form", which allows exploring many things that could not be done on fully preserved buildings.

CONCLUSIONS

Archaeological research has shown that the oldest part of the Kholm castle was built of two types of stone – local green glauconitite and white limestone (probably imported, which protrudes in much smaller quantities compared to glauconitite). The use of glauconite stone in the construction of architectural buildings of the 13th century should be considered a unique construction phenomenon on the territory of Kyivan Rus' and Poland.

The study revealed a wide variety of techniques for hewing, carving, and surface treatment of stone blocks and parts. Since all of them are used for processing glauconitite, masons used them in the 13th century, because only during this period the construction of the residence of King Danylo Romanovych took place from this material. The results of the comparative analysis demonstrate the use of traditional medieval tools and techniques.

The technological features of the local Kholm stonemasonry school of the 13th century highlight the construction and architectural means, tools and techniques typical of the construction team of the chronicle artist-carver Avdii. The revealed methods of working with the stone indicate that a highly qualified team of masons worked at the Kholm castle, but no evidence was found that it was specialists brought from abroad. Instead, the presence of a chronicle mention of the master Avdii proves that these were performers of the local, Kholm or Galician school. Belonging to the Romanesque technique of building walls and the Romanesque style of decorative elements cannot be a convincing argument about the foreign origin of masons. The study is yet another evidence of a mature and long-lasting tradition of Romanesque Ukrainian architecture with centres in Peremyshl, Halych, Volodymyr, and Kholm in the 13th century.

The construction of stone walls in Kholm takes the form of masonry technology "opus emplectum", which was a characteristic feature of the construction of buildings of the Romanesque architectural style of the 12th-13th centuries. The construction of the walls in Kholm is characterised by the use of blocks with a protrusion in the cornerstones. This technique testifies to the high professionalism of the masons.

In general, the presented material is an addition to the picture of architectural and construction craft in Ukraine-Rus' in the 13th century. The results can be used to build hypotheses about the quantitative composition of the construction artel, the distribution of professional responsibilities among its members, and the direction for further research can be compared with construction techniques and technologies of other schools of the 13th century – in Halych, Sandomierz, Krakow, Buda, Esztergom, Poznan, etc.

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CONFLICT OF INTEREST

None.

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Технологія мурування стін і обробки кам'яних матеріалів у будівлях замку XIII століття короля Данила Романовича в Холмі

Анотація. Актуальність дослідження зумовлена великим культурним значенням замку короля Данила, одного з незвичайних архітектурних об'єктів XIII ст. Русі. Мета дослідження – розкрити будівельні технології, техніки обробки і різьблення архітектурних деталей з каменю, що їх застосовано при зведенні замкових об'єктів. Методика дослідження базується на детальному аналізі залишків будівель та окремих будівельних чи архітектурних деталей, які відкриті в результаті архітектурно-археологічних досліджень. У статті проаналізовано характеристики застосованих природних каменів. Археологічні залишки оборонної стіни, веж, фундаментів та стін кількох будівель, призначення яких ще не вияснено, презентують об'єкти створені високопрофесійною будівельною майстернею. Розкопки виявили велику кількість різьблених декоративних архітектурних деталей з глауконіту та вапняку, використання яких свідчить про багатство архітектури та презентує конкретні архітектурні форми романського стилю. Замок на першому етапі будувався лише з каменю, на другому – застосовувалася також цегла. Найстаріші споруди були зроблені з натурального каменю-глауконітиту. Крім місцевого зеленого глауконітиту, застосовано також пісковик, вапняк та скам'яніла крейда. Цікавою особливістю замку є застосування типової романської технології мурування стін, технік тесання кам'яних блоків та різьблення декоративних кам'яних деталей. За результатами досліджень можна ствердити, що тут застосовувався стандартний для того часу набір ручних інструментів. Залишки різьблених кам'яних деталей показують багатий пластичний вистрій фасадів та інтер'єрів замку. Подібні вироби та технології не зустрічаються в інших тогочасних замках Русі. Знахідки каменярських інструментів у замкових руїнах дозволяють припустити, що більша частина технологічного процесу обробки каменю відбувалася тут же – на замковому дворі. Результати дослідження дозволяють вперше представити детальну характеристику каменярської артілі «Майстра Авдія» – персонажа літописних рядків про будівництво замку в Холмі

Ключові слова: будівельні матеріали; архітектурні деталі; камінь; техніка обробки; каменярські інструменти