Geotourism Aspects of Building Stone Use (Romanesque Style and the Onset of Gothic) in UNESCO Heritage Sites of the Historic Centre of Prague for Construction and Architectural Purposes

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Abstract

In terms of architectural development, Prague is one of the classic examples of the application of individual Western European building styles. For this reason, Prague - Historical Centre was rightly included in the UNESCO World Heritage List in 1992. This city, the residence of monarchs, has undergone significant development since the early days of its construction. The Romanesque and Gothic style here greatly completes the scenery of this city. The stone beauty of Hradcany with St. Vitus Cathedral, Charles Bridge and other historical buildings are among the most visited sights of this city. Tourists can learn more about the historical facts about the construction of these buildings from the guides, but the building stone and its sources are practically not paid attention to. For this reason, the aim of this work is to introduce and link the construction of the Romanesque and Gothic periods with a description of the different types of stone used in their construction and their source areas. The importance of this link will help both architectural research and the development of new forms of tourism.

Keywords: *Prague, Romanesque style, Gothic style, building stone, construction, geotourism*

1. Introduction

Prague is the largest city in the Czech Republic and one of the largest in Europe. The construction of this city has been continuous since its foundation and it is still growing today. For this reason, we can see a wide range of building technologies in many of the buildings that were inscribed on the UNESCO list in 1992. In this case, it is a valuable group of buildings represented by many architectural styles. The oldest styles, Romanesque and Gothic, are particularly striking from the outside with their use of natural stone. During this period, local stone was the main material used in the construction of the city. The building techniques used at that time already show the originality and maturity of the construction. The knowledge of the characteristics of the local stone, and later of the stone found in the surrounding area, was at the origin of the construction of these jewels. The underestimation of the knowledge of the physical and petrological properties of rocks is still very common today. Even today, builders often use inappropriate types of stone, such as those that are subject to rapid weathering, and the subsequent need to replace this material makes these buildings considerably more expensive. This paper focuses on the building stone used in the construction of Romanesque and Gothic buildings in Prague. Based on the geological structure of the study area, the areas and localities where these materials were mined and how they were used are highlighted. These resource sites are also of interest because of the need for ongoing restoration work today and in the future. If in the past inappropriate types of replacement aggregates and construction methods were sometimes used, this problem still needs to be addressed today. As a centre of national tourism, Prague can now promote its history and the geoscientific component of tourism, which is closely related to the construction of the city.

2. Geological foundation of Prague

Prague is interesting not only for its history, but also for its varied geological subsoil [1-6]. The area is already formed by rocks of the Proterozoic. The Palaeozoic is represented by the Ordovician to Devonian. The Mesozoic is represented by the Cretaceous, and Tertiary (Neogene) and Quaternary (Pleistocene) rocks are also present. The more resistant types of rock (boulders, quartzites, etc.), as a result of erosion, subsequently contribute significantly to the geomorphology of the Prague relief. They form elevations and rocky ridges on which some of the city's landmarks stand (e.g. Hradcany Ridge or Vyšehrad Rock).

2.1 Proterozoic

The oldest rocks here are Proterozoic clastic sediments. In the north-western part, the oldest Kralupsko-Zbraslavská unit with inserts of boulders occurs. The upper parts of this unit also contain mainly acid volcanics and, to a lesser extent, basic rocks (spilites). In the south-eastern part of the unit is the younger Štěchovice unit, built up by monotonous flysch. At the end of the Precambrian and the beginning of the Palaeozoic, the Cadomian mountain-building phase took place here. The wrinkled rocks were subsequently affected by denudation.

2.2 Paleozoic

Ordovician: At the beginning of the Ordovician period, the sea trembles here and continuous sedimentation takes place until the Middle Devonian. The rocks were deposited in the so-called Prague Basin (an elongated depression in the NW-SE direction). The historic centre is built on Ordovician rocks. This formation occupies the largest area here and the substantial rocks are low-resistant Aleuropelitic sediments. The resistant rocks, light quartzites and flysch beds (alternation of hard sandstones and quartzites with finer-grained rocks) are also preserved in this period, but to a lesser extent. There are few igneous rocks in the Ordovician. These are, for example, diabases (Řeporyje) or vein migmatites - minettes (Dvorce - Bohdalec - Štěrboholy belt).

Silurian: The continuity of sedimentation at the beginning of the Silurian is not interrupted. In the lower part there are graptolite schists, which pass into calcareous schists in the overburden and into tuffaceous limestones in the vicinity of volcanic manifestations. In the upper part, limestones predominate. Volcanic activity is evidenced here by automorphically metamorphosed diabases and their volcanoclastics.

Devonian: Limestone sedimentation also continues continuously from the Silurian at this time. The type localities of the Lower Devonian, after which its stages were named - lochkov, prag, zlíchov. In the highest stage of the Lower Devonian (dalej) the sedimentation changes to calcareous clay shales. This sedimentation changes back to calcareous sedimentation (Trebotov limestones and Choteč limestones (eifel)), and then, in the overlying strata, there is sedimentation of sandy-clay flysch (givet), which closes the sedimentation in the Prague Basin. In the Upper Devonian to Lower Carboniferous period, the Variscan mountain-forming phase took place, during which the rocks of the Palaeozoic and the already wrinkled rocks of the Proterozoic were eroded.

2.3 Mesozoic

Cretaceous: This formation is represented here only by the Upper Cretaceous. Rocks from the Carboniferous to the Lower Cretaceous are not preserved here. The denuded surface with lakes and marshes (with clay deposits, low-grade coal seams and then sandstones) was overlain by the transgression of the Upper Cretaceous sea. The sedimentation of glauconitic sandstones (Cenomanian) and tuff (Turonian) is the last marine sedimentation in the area. The sediments have not been affected by mountain-forming seepages and therefore have an almost horizontal position of the strata.

Tertiary: Direct traces of geological processes are only found in this area and its surroundings in the Neogene. These are fluvial and lacustrine sediments, which are found at higher altitudes (e.g. White Mountain or below Ladvi) and do not correspond to the current river network.

Quaternary: This is the period when the Bohemian massif is uplifted. As a result of changes in climate, ice ages and interglacial periods, river terraces are formed by incising streams, which in Prague form stepped terraces. The arid climate is also strongly influenced by aeolian activity - sphagnum and weathered sands. In warm stages, soils are formed.

3. Building stone in the architecture of Prague and geotourism

A brief overview of the geological development shows that Prague has a very interesting bedrock structure. This structure is also linked to the diverse range of raw materials that have been mined since the early days of the city's construction. Today, the stone beauty of the monuments can be admired especially in the buildings of the Romanesque and Gothic styles. However, the use of stone and its variety, especially in the decoration of buildings, can also be found in other periods of the construction of this metropolis. In the early days of construction, the building industry used building stone both from sites in the area of today's Prague and from its immediate surroundings. Over the centuries, quarried and processed stone was also incorporated into the construction of roads and pavements. For this reason, Prague is a perfect example of stone quarried here and used in the construction of architectural monuments. Already the first stages of the construction of stone buildings used mainly younger Mesozoic rocks, which were opacities and sandstones. These petrographic types in unplastered masonry were a suitable choice in terms of workmanship and sufficient resistance to time. The Prague quarries also provided stone from earlier periods. Typical, for example, is the varied, colourful range of different types of Palaeozoic limestones, also containing fauna (orthoceri), which are described in many geological guides. From this point of view, Prague is therefore the most ideal large city where geosciences, in terms of stone in architecture, can join classical tourism [3], [7-9], [10-15].

4. Building stone in the architecture of Prague and geotourism

From the very beginning of Prague's construction, stone was used as a building material alongside other raw materials such as wood. In the beginning, stone was used that was found on the territory of present-day Prague or in its vicinity. In the early stages, unworked stone in its original, decayed state was also used. In the pre-Romanesque phase of Prague's construction, stone was not used in practice. The Romanesque style [7], [11], [13-20]. adopted the knowledge of ancient construction. The buildings are simple, symmetrical, with massive stone walls and the use of semicircular arches (entrances, windows, vaults). Cross vaults, thick pillars and decorative columns were also used. Romanesque buildings were constructed in western, central and southern Europe. In

Eastern Europe, however, the Byzantine style was still in use. As far as the construction of Prague in this period is concerned, the buildings from this period were mainly built from Upper Cretaceous sedimentary rocks. For a long time it was mainly worked limestone (dusty siltstone) and less sandstone that was used. These rocks were quarried in the immediate vicinity of the buildings. They came from places in Prague such as Bílá hora, Strahov or Petřín. Later, with the improvement of transport and the bridging of the Vltava River, stone was imported from more distant places. In the second half of the 12th century, Prague was considered one of the most beautiful stone cities in Central Europe. Nowadays, we have the opportunity to learn more about many of the ruined buildings from this period through archaeological excavations carried out in preparation for the construction of new buildings or the modernisation and reconstruction of existing ones. However, these remains are often not treated with the respect they deserve, as shown below. To this day, the typical examples of the Romanesque style (11th-13th centuries) in Europe are mainly ecclesiastical buildings such as rotundas and basilicas. This is also the case in Prague.

4.1 Rotundas

Rotundas represent a significant part of the preserved Romanesque monuments in Prague. They are buildings with a circular nave on the eastern side supplemented by an apse, a niche where the altar mensa was located. Unfortunately, some of these buildings have not survived to the present day. These were: the Rotunda of Unknown Consecration (Dolní Chabry), the Rotunda of St. John the Baptist (Malá Strana), the Rotunda of St. Wenceslas (Malá Strana), the Rotunda of St. Pankrác (Nusle), the Rotunda of St. Lawrence (Staré Město), the Rotunda of St. John the Evangelist (Vyšehrad) and the Rotunda of St. Vitus (Prague Castle, on the site of St. Vitus Cathedral, Hradčany). Those that have survived to the present day have undergone various minor architectural modifications over the centuries. In the course of the following centuries they were used for other purposes and some of them were threatened with demolition, especially in the 19th century during the reconstruction of the city. Of these preserved rotundas, the following have survived in Prague:

Rotunda of the Finding of the Holy Cross (intersection of Konviktská and Karolína Světlé streets, Old Town), 12th century, built of smaller bricks

St. Longin's Rotunda (Na Rybníčku Street, New Town), early 12th century, later Gothic and Baroque modifications, larger sandstone blocks

Rotunda of St. Martin (Vyšehrad), 11th century, mainly ashlar blocks, less sandstone. More recent reconstructions include a neo-Romanesque portal of Gorizia sandstone, pink limestone (Slivenec marble) used in the interior (altar mensa, steps)

Rotunda of St. Mary Magdalene (Church of St. Mary Magdalene, Prague - Přední Kopanina), beginning of the 12th century, ashlar blocks, ashlar was mined in the local quarry (today's natural monument Opukový lom)

4.2 Basilicas, churches

These buildings had a rectangular plan with an internally longitudinally divided space by columns in three or more naves. Towers were also part of these buildings. The chancel was located in a niche (apse) that faced east. Almost two dozen of these buildings are mentioned in Prague. Some of them disappeared in the past centuries and their remains were discovered during archaeological excavations that took place here in the past. In some cases, there have been irreversible losses in cultural history. One such example is the uncovering of the foundations of the Church of St. Benedict in the Old Town in 1968, when archaeological excavations were carried out before the construction of the underground garages of the Kotva department store. Despite protests, these masonry remains and the adjacent graves were destroyed during subsequent construction. Insofar as these monuments have survived to the present day, we can often discover transitions from the late Romanesque to the early Gothic style, such as the Church of St. Francis of Assisi (the Agnesian Monastery) or the Church of John the Baptist Na Prádle. Some of the buildings can also be seen in more recent reconstructions. A typical example is the second oldest church in Prague, the Basilica of St. George, with the burial place of the Přemyslids and the adjacent oldest Czech female Benedictine monastery. After the destruction of this building by fire, a Gothic restoration and completion of the church and the monastery was carried out in the 14th century. In the 17th century the building acquired a Baroque appearance with the addition of a new chapel. At the turn of the 19th/20th century, the interior was restored to the older original style. These alterations also present a problem in determining what is the original stone used and what was used in later alterations and additions. Chalk sediments, siltstones and sandstones are also the building stone of these monuments.

Other buildings constructed during this period are secular buildings. Only part of Prague Castle has survived to the present day.

4.3 Old Royal Palace

This building forms the central part of the southern wing of Prague Castle. The palace began to be built during the reign of Prince Soběslav I in the first quarter of the 12th century (it has been archaeologically confirmed that the original princely residence, built mainly of wood, was built here as early as the turn of the 9th and 10th centuries). The palace served as the residence of Czech princes and kings until the 16th century. The throne room with a chapel has been preserved from the Romanesque period. It is built of unplastered block masonry made of limestone. As a result of burning and subsequent reconstructions, this monument has also been preserved to this day with a non-original appearance.

4.4 Romanesque houses

Information about these buildings, which have not survived to the present day, is continually being gathered from archaeological investigations carried out in areas of new construction or conversion of existing buildings. The first recorded discovery of such a house took place in 1898 during the demolition of one of the newer houses in Týnská Street in the Old Town. The construction of Romanesque houses began in the second half of the 12th century. By now, around 70 such buildings have been discovered. Originally, Prague was expanding in close proximity to Prague Castle. Already in the 10th century, many wooden buildings were built in the Lesser Town area, which completely filled the area. Later, from the 11th century onwards, the opposite bank of the Vltava River in the area of the Old Town also began to be settled. The beginnings of the construction of stone houses in the Old Town start around the middle of the 12th century. The buildings were two to three storey buildings. The ground floor, which was partially below ground level (up to 2 metres), was probably used for storage and trade. Almost all of the buildings had vaults on the ground floor (exceptionally built on higher floors), which have survived in most of the buildings studied. The other floors were mainly used for housing. The entrance to the house was at the rear of the building, where there was a courtyard or garden with outbuildings or a well. The windows were mostly in the rear of the building. It is still unspecified who the original owners of these houses were. The most approved view is that they were foreign merchants and money changers. The stone used to construct these houses was primarily cinder block and sandstone. The presentation of the stone remains of the Romanesque palace can also be found in the premises of the multifunctional complex Palladium, the construction of which took place between 2005 and 2007. During the archaeological research there were discovered 3 stone houses, one of them was the mentioned palace and wooden houses. The survey showed that the walls of the palace were about 1 metre thick. On the outer side there was perfectly worked stone, the so-called blockwork, while the inner part was made of smaller, unworked fragments of stone and binder. This reconstruction of the former Jiří of Poděbrady barracks also ranks as one of the most serious negative impacts on the original architecture of Prague. This construction also threatened to remove the Prague Monument Reserve from the UNESCO World Heritage List.

5. Stone in Gothic architecture - typical, preserved examples of Prague Gothic

France was the birthplace of the Gothic style. It was here that this new style began to be used as early as the 12th century, when the Early Gothic period began. According to scientific research [7], [14], [15], [21-25], the *Early Gothic (Premyslid)* period in the Czech Republic began a little later, in the 13th century (the subsequent periods of Gothic in the Czech Republic roughly coincide with the stages of this style in France). The buildings are still characterised by their solidity, with fixed windows in thick walls. In Bohemia and Moravia, religious buildings as well as secular architecture have been preserved from this period. A typical example of this architecture is the Old Synagogue in Prague's Old Town. It is a rectangular building with two naves and a cross-ribbed vault, built in the early Cistercian Gothic style. It is also the oldest surviving Jewish synagogue in Central Europe. The stone used for its construction was high quality sandstone. The building also bears the marks of later, sometimes less successful interventions.

Another period, mainly in the 14th century, is the *High (Luxemburg) Gothic period*. This period is significant for Prague because the rulers of the time, John of Luxembourg and especially Charles IV, emphasised the importance of this historically significant city through their building development. As far as the reign of John of Luxembourg is concerned, important religious buildings from this period are the buildings of the Minorite monastery and the adjacent Church of St. James in the Old Town. This is where John of Luxembourg had his residence. A courtyard with a small church was built on this site as early as the 12th century under Přemysl Otakar I (the exact location and appearance of the church is still unknown).

In the early Gothic period, during the reign of Wenceslas I, a monastery was built here, which burnt down in 1316. Subsequently, the monastery was restored and rebuilt by John of Luxembourg and his wife Eliška Přemyslovna. This reconstruction also made the church the highest and largest sacral building in Prague. The current appearance of these buildings corresponds to the Baroque style after a later fire and later restoration. The use of sandstone is also found in the building. Important religious and secular buildings are especially those built during the reign of Charles IV. These include the classical monuments of Prague. Among the religious monuments is the St. Vitus Cathedral. It is the beginning of its construction in the premises of Prague Castle. It is also the first cathedral of the French type in this territory. In the 19th century it was completed in the Neo-Gothic style.

Sandstone was also used in the oldest Gothic part of the building. Classic examples of secular monuments from this period are the construction works at Prague Castle, Charles Bridge, the Old Town Bridge Tower, the Karolinum and the Old Town Hall. The founding of the New Town in 1348 is also of great importance in this period, which placed Prague as one of the largest European cities.

The Late (Jagiellonian, Vladislav) Gothic period (15th century to the beginning of the 16th century) appears mainly on secular buildings, such as the ongoing reconstruction of Prague Castle (Vladislav Hall) or the construction of the Powder Tower as the beginning of the Royal Route. In summary, stone also plays a very important role in this style. If it has not been covered by later reconstructions, its beauty can still be admired in these buildings today. In this style, opaca has already been replaced by sandstone. Opuka thus became the stone used mainly in ordinary masonry. The lightweight construction of the buildings uses sandstone not only from the Prague part of the basin, but also from the surrounding area. For the construction of the Gothic buildings, mainly Upper Cretaceous fine-grained sandstones from eastern Prague - Hloubětín and the localities of Sluhy, Brandýs nad Labem, Zápy or Kostelec nad Labem situated northeast of Prague were used. Older coarse-grained arkosic sandstones from the Kamenné Žehrovice permokarst, a locality near Kladno, have also been used. In the Gothic buildings we also find well-deposited and polished Paleozoic limestones from the Radotín valley. A typical limestone is the 'Slivenec marble', pink to red-brown in colour. In the lapidarium of the National Museum, there is a Gothic tombstone made of this limestone, which was originally in the Church of St. Vitus.

The use of this stone is very common during the Renaissance. From the Paleozoic sites, for example, the red to brownish-red limestones of Suchomast, the black-grey to black limestones of Kosořská, Karlická and Ortocerská (Lochkovská) began to be used. Decorations made of these limestones can be found, especially in later times, in many church buildings (sprinklers, lining, picture frames, thresholds or paving). The chapel of St. Wenceslas in the Church of St. Vitus also offers interesting decoration. Here, polished slabs of semi-precious stones were used to line the walls up to a height of 3 metres. They come from domestic and foreign deposits. From the Ciboušov locality there is a granite made of amethysts and jaspers, from Poland there are chrysoprase, from Saxony there are topazes, red porphyries from Egypt and green porphyries from Greece.

6. Conclusion

The Prague Conservation Area is not only the largest in the Czech Republic, but it is also one of the largest in the world. The continuous settlement of this area since the early Paleolithic proves that this area had an important position long before the founding of Prague. The building of this city is also continuous, incorporating all the classical building styles of the European West. In this respect, the Romanesque and Gothic styles are at the origin of the building of stone architecture in Prague.

From an artistic, aesthetic and cultural-historical point of view, they have a significant position here. This stone architecture placed the city at the forefront of Central European centres as early as the Romanesque period. Although building stone is the most important material used in the construction of these buildings, its detailed description and species identification is absent from many information sources. Knowledge of this material and a closer identification of the source areas is and will be a necessity for the conservation of these historic buildings. The necessary replacement of weathering-damaged segments from these buildings has often in the past also disregarded the need to use identical stones from the same locations.

In terms of tourism, Prague is one of the most visited cities in the world. More than 80 % of tourists coming to the Czech Republic go to Prague. In terms of the development of non-traditional forms of tourism, there is also the development of geotouristic and historical exploration of Prague and its surroundings. These new possibilities of tourism development have also been described for other selected sites [26-28]. In the Czech Republic, there are seventeen UNESCO protected sites in addition to Prague [29].

The possibility of bringing the origins of Prague's stone architecture and geological sites closer to those interested in where the original building material was mined can also complement and even improve the tourism offer not only in this city, but also in its surroundings.

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