Geotourism interesting locality with Remediation of the bedrock and restoration of Spiš Castle - UNESCO heritage site

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Abstract. Understanding the structure of the geological subsoil should be the first stage in the construction of any major building. Therefore, if the problem of rescue and restoration of various historical buildings is currently being addressed, it is necessary to study their subsoil in detail. Among the important historical buildings that have been preserved in Slovakia are numerous castles and chateaux. Nowadays, many of these buildings need to be extensively restored to prevent their gradual devastation. The issue of rehabilitation of some buildings has been addressed for several decades. The reasons for the rehabilitation of these buildings have varied. In the case of the ruins of Strečnian Castle and its subsoil, it was primarily the safety of traffic on the adjacent important road. In the case of Spiš Castle, it is a monument of world importance. It is one of the largest castle complexes in Europe. The beginnings of the construction of this complex date back to the 11th century. Its current state is due, among other factors, to the instability of its geological subsoil. For this reason, the stabilisation of the travertine body, which has been severely damaged, particularly by tectonics and karst processes, has already been addressed in the past. The solution of this problem in the past has already produced positive results, but due to exogenous processes and, hypothetically and certainly, seismicity, the bedrock may move again in the future. For this reason it is necessary to pay attention to continuous monitoring of the movement of its rock blocks. As far as the castle itself is concerned, its current state is mainly due to the fire at the end of the 18th century, followed by its rapid devastation. In view of the world importance of the castle, the restoration of the site may therefore also take other directions. One possibility is, for example, its reconstruction according to contemporary records, which would bring its final appearance even closer to its original grandeur.

1. Introduction
In the past, castle buildings fulfilled many functions. The construction of these buildings was also carried out from the point of view of defence on elevated formations, which were usually difficult or not accessible from some sides. From a geological and geomorphological point of view, the Slovak Republic has a great variety of bedrock and geomorphological shapes. In the past, this variability was used to build numerous castles, which have survived to this day. It is also because of this variety of terrain that Slovakia is the first country in terms of the number of castles built. More than a hundred of these
buildings have survived to the present day, but fewer have been irrevocably destroyed. In order to protect these buildings, nowadays, deserved attention is paid to their conservation or their professional completion. In the past, attention was paid only sporadically to the issue of the stability of the subsoil of these buildings. Attention has been paid mainly to perfectly preserved castle buildings, including, for example, Orava Castle. Other objects on which attention was focused were, for example, ruins of castles whose subsoil was threatened by adjacent buildings in terms of instability. Among such is Strečniansky Castle situated next to the main road connecting Žilina with Martin. Due to financial and time constraints, some of the buildings were forgotten and this subsequently contributed to their current state of disrepair. The fact that the solution to these problems is not simple and final has been proven several times in the past. Strečnian Castle, which has been the focus of attention for more than half a century, is a perfect example of this, and the problems are not over yet. The monitoring carried out on some of the objects shows us interesting results that can give us early warning of more serious problems that may arise in the study area. A set of methods can now be used to deal with these processes in time to eliminate the consequences. In addition to a perfect understanding of the subsurface, it is also necessary to know which influences from the endogenous and exogenous dynamics of the Earth are strongly present in the area. Various combinations of these factors are also common. Some factors act continuously (weathering processes), others randomly (e.g. seismicity). Different approaches must be taken to dealing with these problems and the effectiveness of the methods used must also be monitored over the long term. Nowadays, we also have several examples from the past where poor measures and surveys have made the situation of the castle building or its substructure even more complicated (e.g. the repair of Strečno Castle). In this work, attention is paid to one of the most extensive castle buildings, Spiš Castle.

2. Spiš Castle

2.1. Geological structure of the castle’s subsoil

The large complex of Spiš Castle is located in the Podhradská lowland in the northern part of the Hornád Basin. The castle is built on a rugged travertine body, in the subsoil of which there are soft palaeogene layers of the flysch complex (mainly claystone and sandstone), whose slope does not exceed 10° to the SW. Significant mineral spring activity, which began at the end of the Pliocene, has created interesting travertine bodies here. The body of Spišský hrad itself reaches the greatest height of these bodies. The travertine (micro to macroporous rock of white to yellow colour) is up to 52 m thick. This is due to the fact that the upper layers of this body were formed in the older Pleistocene period. Geophysical methods have been used in the past to determine the areal extent of this body. Closer investigation and comparison with the surrounding Drevenik body revealed that the original body had already been significantly disturbed during the Pleistocene. As a result, only denudation blocks remain of the original dome-shaped bodies. Erosive-denudation processes have had a greater impact on the flysch rocks and have consequently exposed the steep travertine walls more. Karst processes as well as the action of ice in the periglacial climate were other disturbing factors. The disequilibrium between the weathered upper part of the flysch and the travertine began to manifest itself in creeping movements. This process significantly disturbed the entire travertine body [1, 2].

2.2. Brief history of the castle

Archaeological excavations prove that there were several forts on this site in the past. The site where the castle stands today was already inhabited in the early Paleolithic. In later times, there was a Latin hillfort. With the arrival of the Slavs, the settlement moved to the neighbouring Drevenik. The first castle buildings were built here at the turn of the 11th and 12th centuries, and the castle continued to expand in the following centuries. Today it covers an area of over 40,000 square metres. In the 12th century, a Romanesque castle with a circular tower was built here. The geological bedrock was probably the reason why this tower was soon destroyed. Subsequently, at the beginning of the 13th century, a new tower and a Romanesque castle palace with a chapel were built next to it. This castle was one of the few to withstand an attack by the Tartars. Later, the castle fortifications were strengthened even more. In the 14th century a large castle courtyard was built and in the following century the so-called Lower Castle
was built. This part was protected by a castle wall and also by two residential towers and an entrance tower. A fortified fortress was situated in the centre. Until the middle of the 15th century this castle was a royal castle. This was because in the 12th century the north-east of Slovakia became part of the Kingdom of Hungary. At the same time, important roads crossed in this area and it was also the centre of administration of the wider area. For a certain period of time, the Provost of Spiš was also based here. From the second half of the 15th century the castle was owned by the Zápolský family. Their aim was to rebuild the castle into a noble residence and for this reason the owners extended the castle again with a new chapel and other buildings. During the Renaissance the castle was owned by the Thurz family and then by the Csáky family. They also carried out numerous reconstructions for the functionality of individual buildings. At the turn of the 17th and 18th centuries, however, the castle ceased to meet the demands of the owners at that time, who subsequently abandoned it. Only a small garrison remains in the castle. A fire in 1780 was the beginning of the castle's decline. In 1945 the castle was transferred to the state. In 1961, this monument was included in the list of National Cultural Monuments. Nowadays, the castle is also of importance and significance in terms of world interest. In 1993, together with the surrounding monuments - Spišská Kapitula, Spišské Podhradie and Žehra, it was included in the UNESCO World Heritage List [3-7].

2.3. Rehabilitation of Spiš Castle and its subsoil

The unsuitable geological subsoil significantly affects the stability of the castle buildings. Spišský hrad, which is situated on a travertine hill, is a very valuable object, which has parameters of world importance. The travertine location itself, which exceeds 50 metres in height, is influenced by several factors. The travertine body is underlain by soft palaeogene rocks, which have had a significant impact on the disintegration of the primary travertine body into several blocks. This in turn has also contributed to the occurrence of numerous faults in the travertine. As a result of these disturbances, karst activity has subsequently become pronounced. The most significant karst formations here include two caves, Temná and Podhradská. These caves are relatively large formations. The occurrence of karst manifestations significantly increases the instability of the castle's bedrock. In terms of seismicity, the area is classified as MCS level 6. Neotectonic faults are a potential hazard for the occurrence of these phenomena, which may consequently significantly threaten the stability of this monument. Unfortunately, there is no historical record of whether this area has been affected by seismic activity in the past. Shocks caused by blasting operations in the travertine quarry, close to the Dreveník, may also have an adverse effect. The stability of the castle building itself has been undermined by the use of unsuitable binders. The mortar used here contained travertine rubble. This binder is much more susceptible to weathering and accelerated dissolution.

Based on this knowledge, procedures for saving this monument have been proposed in the past. Initial research and restoration to the form of an architectonic ruin began in the 1960s. Some reconstruction work was also carried out. In later years, a more detailed study of the subsoil was undertaken, and at present, attention is focused mainly on the restoration of the castle itself [1, 2, 8-13].

Crack displacement monitoring - In order to gain a more detailed understanding of crack movements, locations were selected for monitoring these displacements. The first installations of these devices took place as early as 1980. The original three devices were subsequently supplemented with six additional gauges in 1992. After only four years of measurements, it was possible to determine more accurately from the measured data in which parts of the bedrock the situation was most complex. This turned out to be the eastern part of the lower courtyard, specifically between the cross wall and the outer defensive wall (the measured value was 13 mm). Subsequent measures have stabilised this movement for the time being. The measurements also revealed that another, less stable area was the south-eastern part of the Lower Courtyard, near the entrance to the castle (on the travertine part of the Perun Rock). This block was found to be tilted in a south-easterly direction. The measurements also confirmed that the recorded movements of the fissure system are strongly influenced seasonally. They are mainly influenced by
changes in temperature and rainfall. The bedrock of the eastern and western defensive walls was preferably affected. For the Romanesque palace, anchoring rock was proposed. Conservation works were proposed for the remaining parts of the castle. Grouting was used and, where necessary, underpinning using micropiles. Great emphasis was placed on the need to remove vegetation, which also contributed significantly to the weathering of the carbonate rocks, and also to remove weathering.

Staged reconstruction of Spiš Castle - The importance of this monument was reflected in the plan of the Slovak National Museum for the full reconstruction of the castle complex. The first stage of the reconstruction of this monument has already begun in recent years. Rehabilitation was carried out by anchoring the subsoil under the western palaces and walls. This stage also included the main utilities. These included monitoring of the security of the site, electrical distribution, water and sewage systems. An active lightning protection system was also constructed. Other important steps were the comprehensive reconstruction of the so-called Captain's House, the conservation of the main Renaissance ("Thurzo") entrance gate and the rehabilitation of the lower courtyard walls. The issue of stabilising the foundations and the base of the fortifications will be addressed in the next stage of the restoration. The cost of the second phase, which is currently starting (2021), will amount to just under 5 million Euros. The project documentation will focus on the rehabilitation of the subsoil, the eastern palace and walls, as well as the upper courtyard. Subsequently, the reconstruction of the middle and lower part of the castle will be prepared. The total cost of the restoration, which is expected to take around 10 years, will be around 20 million Euros.

3. Conclusions
The Spiš Castle is an illustrative example of the importance of the geological subsoil for the stability of buildings. Unsuitable subsoil was most likely responsible for the rapid destruction of, for example, the Romanesque tower at the beginning of its construction. The castle complex is built on a travertine pile, under which there are flysch deposits. The action of mainly exogenous geological factors had a significant impact on the disintegration of the travertine body into individual blocks. The relatively rapid movements of the fissures, which have now been monitored for some time, have confirmed the need for priority rehabilitation of the underlying rocks. However, this rehabilitation will have to be updated in the future based on the movements that are still being recorded. In recent years, a major, long-term and costly restoration of the entire castle complex has also been undertaken. As the castle complex is very large in area, a phased approach has been taken to the restoration of this important monument of world significance.

Acknowledgment(s)
Authors thank the Faculty of Mining and Geology, VSB – Technical University of Ostrava for the support of the project (SP2021/59) which is the base of this article.

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