

The boom-and-bust cycles of the Spiš travertine extraction during nine centuries (northeastern Slovakia)

Daniel Pivko

Department of Geology and Paleontology, Faculty of Natural Sciences, Comenius University, Ilkovičova 6, 842 15 Bratislava, Slovakia; daniel.pivko@uniba.sk

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Abstract: Whitish high-quality Spiš travertine (Pliocene) was the most used natural stone in Slovakia for ashlar, architectural elements, cladding, flooring, and plastic products. An analysis of written sources, historical maps, aerial and lidar-derived images, and research of travertines on buildings enabled the definition of boom-and-bust cycles of the travertine block extraction. From the 12th to the 13th centuries, the travertine was extracted from block fields and weathered travertine outcrops for the Spiš castle construction. Walloon and German immigrants from Nordrhein region brought skills of processing a limestone and dressed travertine into fine architectural elements for the Spiš castle and churches. From the 14th to the half of the 19th centuries, Spiš travertine blocks were used very rarely, since the German immigrants from Saxony preferred to use sandstones. From the 1860s to 1918, the growing travertine production achieved regional significance due to suitable economic conditions. Stonemasons from northern Italy brought experience with limestone processing and founded opened quarries on travertine outcrops of the Dreveník site. Stonemasons initially used natural joints in travertine massifs to break off the blocks with hand tools and later a machine drilling at the end of the 19th century. The industrial period with national and European travertine use occurred when Czechoslovakia was founded (1918–1939). The machine extraction and processing produced precision stone slabs and tiles. The Spiš travertine soon became a popular stone in the 1930s and was used in most Slovak cities and towns, additionally in Czech cities. The Spiš travertine reached a great national significance between 1950 and 1955 and between 1965 and 1975. The decreasing block yield in the Spišské Podhradie quarry was caused by adverse geological conditions and inappropriate blasting. A demand was compensated by an increased volume of extraction but hampered by a clash of interests with nature protection. A newly discovered deposit in a national natural reserve was closed after 15 years. The reduced quarrying and processing of travertine modern products continue up to the present day in Spišské Podhradie.

Keywords: quarries, architecture, products, natural stones, age distribution, travertine

1. INTRODUCTION

Slovakia is rich in travertines. 67 municipalities have travertines in their territories. About 170 travertine forms are related to deeply circulating groundwater that emerged in mineral springs. Travertines were mostly developed in the form of spring mounds. The high-quality travertines were used as ornamental stones, the most important in Slovakia. The dominant Spiš travertine (*spišský travertín* in Slovak) can be visible on public buildings almost in all Slovak cities and towns.

Dense travertines are very valued as building and decorative stones and have been extracted in many locations. Its societal value results from a combination of its sufficient compressive strength with lightness thanks to its high porosity, which provides low thermal conductivity, and good sound insulation. The natural weakness of travertines along bedding and lamination is decreased by cementation. The dense travertines are preferred for their pleasant soft colours and patterns. The travertines are easily worked and can be cut, filled, and polished. Quarried blocks of travertine find use in a lawn or a garden inside a rockery. Travertine sculptures have a particular style (Pentecost, 2005).

The travertines have been used by Egyptians since the 1st Dynasty ca. 3200 BC (Emery, 1961). A cut travertine slab was excavated in an early Bronze Age cemetery in Budapest (ca. 1000

BC; Dobosi, 2003). Many examples of travertine utilization are from Greek, Etruscan, Roman, and Persian buildings. The Romans used travertine on a large scale for building and tomb construction, e.g., Forum Romanum and Colosseum in Rome, Perugia, Hierapolis in Turkey, and Budapest in Hungary. In the second half of the 19th century until 1918, Hungary was abundant in monumental travertine memorials. Hence, the societal value of travertine is obvious.

I have studied Slovak travertines in detail for 20 years, especially in terms of building/decorative stones on buildings. Travertine facies are visible on travertine building cladding, where structures and textures were cut both in vertical and horizontal directions. The coalesced mounds of the Dreveník and the Spiš Castle and the mounds in their neighbourhood were studied in most detail being substantial travertine sites in Slovakia (Fig. 1; Pivko, 2016, 2018, 2021, 2022; Pivko & Vojtko, 2021).

Written sources (documents) offer information about the extraction and building history of the Spiš travertine. The most comprehensive and valuable source of information about the extraction was the database of old Hungarian quarries, where Schafarzik (1904, 1909) mentioned a historical quarry with block production on SE of the Spišská Kapitula (NW Dreveník), a smaller quarry with block extraction at the Ostrá hora site, and a quarry on the Dreveník near Hodkovce for

lime production. Kubíček (1929) and Hájek (1935) provided some information about extraction, processing, and the use of the stone, especially in Czechia. Ivan (1941a, 1943, 1944) in papers and monography of Slovak travertines reported on the situation at the turn of the thirties and forties, about 7 quarries in the Dreveník area, processing workshops in Spišské Vlachy and Krompachy, and typical stone products under the name ‘Spiš travertine’. The travertines as mineral resources have been studied by Andrusov (1943), Zorkovský (1963), Čabalová (1969, 1989), Zuberec et al. (2005), and Ružička (2006). Information on travertine volume extracted per year is published in reviews (e.g., Tréger & Baláž, 1998; Baláž & Tréger, 2002; Baláž & Kúšik, 2005; Šoltés et al., 2020). A wealth of valuable information on the Spiš travertine extraction and research is provided in unpublished technical reports (Krejčíř, 1955; Dojčáková et al., 1967, 1968; Hudáček et al., 1976a,b).

Ivan (1941a, 1941b, 1942, 1943) mentioned that the Spiš travertine was exported to many European countries and overseas. Examples of travertine use in Slovakia and especially in Bratislava were published in Mišík (1952) and Pivko (1999, 2005, 2007, 2009). Čabalová (2013) dedicated a special chapter to Slovak travertines, their extraction, processing, and use.

This publication aims to describe the history and places of the Spiš travertine quarrying in the last 900 years, especially for the block extraction and discuss the causes of the extraction growth and decline. The paper draws attention to a speciality of the Spiš travertine, which occurrence and important use should be specially protected.

2. GEOLOGICAL SETTING OF THE SPIŠ TRAVERTINE

Slovakia as a mountainous country belongs to the Western Carpathians and partly to the Pannonian Basin, which are north-eastern portion of the Alpine Orogeny Belt. The internal part of the Western Carpathians is built by a nappe stack, which is represented by thick-skinned tectonic units covered by a thin-skinned nappe system. The thin-skinned nappe pile is composed predominantly of Mesozoic variable carbonate rocks. During the Paleogene, the nappe stack was covered in the north by marine flysch sediments. Horst and graben system in the internal zones of the Western Carpathians was the result of the Neogene strike-slip to extensional tectonic regime in which volcanic products covered the earlier tectonic units, especially in central Slovakia (Hók et al., 2014, 2019). The modern relief formation relates to the planation of a large part of the Western Carpathians at the Miocene/Pliocene boundary. It was the beginning of the dome morphostructure formation before 4 to 6 Ma with the main stage of the uplift to the Late Pliocene (Minár et al., 2011).

The Late Miocene and the Pliocene are the beginning of Slovak travertine formation. Ivan (1941a, 1943, 1952) describes approximately 35 and Kovanda (1971) 70 Slovak travertine localities including a detailed list of references. Recently, the most known Slovak travertine sites were studied by Polish (Gradziński et al., 2008, 2014, 2015; Wróblewski et al., 2010) and systematically by Pivko & Vojtko (2021), and Pivko (2021).

Travertines (thermogene travertines *sensu* Pentecost, 2005)

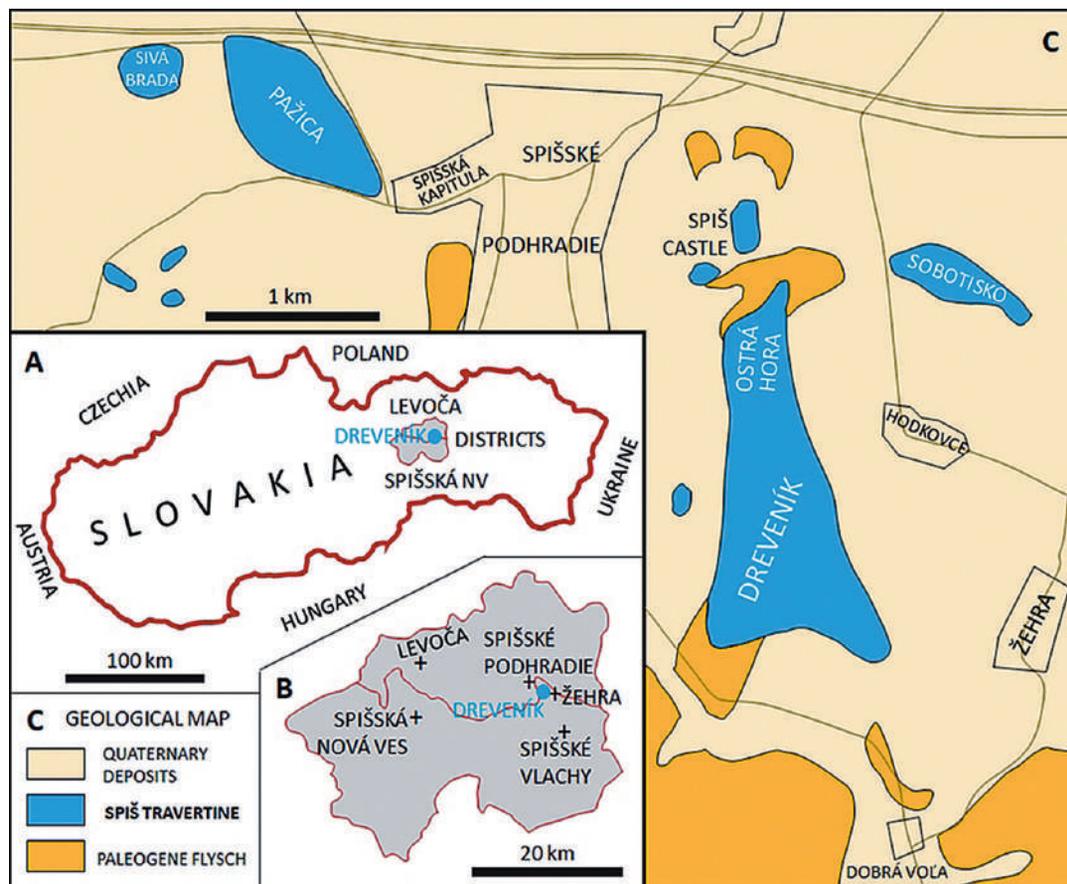


Fig. 1. Geology of the Spiš travertine in the Spiš region: A – position in Slovakia, B – position in Levoča and Spišská Nová Ves districts of the Spiš region, and C – simplified geological map and explanations.

are located near springs, fed with deeply circulating thermal waters, generally over 30°C that are rising along tectonic faults. The travertine water is chiefly characterized by very high HCO₃ content (> 7 mmol·l⁻¹). The travertines are typified by high depositional rates, regular bedding, lower porosity than tufas, and an inorganic crystalline and organic microbialite fabric (Capezzuoli et al., 2014).

Compacted travertines and fresh-water limestones, suitable for a block extraction, originated in the Tortonian, Pliocene, and Pleistocene periods from the deep mineral waters circulating in Mesozoic carbonates, which are located under impermeable Paleogene flysch (the Spiš, Ružbachy, Bešeňová, and Ludrová travertines) or Neogene deposits of volcanic origin (Levice).

The Spiš travertines were mostly accumulated in the form of spring mounds on undulated Paleogene flysch sediments (Gross et al., 1999; Mello et al., 2000) during the relatively warm climate period of the Late Pliocene (3.6–2.6 Ma; Pivko & Vojtko, 2021). Travertine forms were developed as smooth slope cascades with overlying prograding lobes, indicated by angular unconformities. The cream-coloured bedded travertine with white patina is composed of crystalline crust travertine alternated with microphyte travertine (Fig. 2a). Crystalline crusts consist especially of fan- to feather-like crystals. Macroporous microphyte travertine is built of cyanobacteria and algae mats and crusts. Individual mounds were aligned to coalesced mounds in the form of the oval Spiš Castle and the triangular Ostrá hora – Dreveník plateaus about 60 m in thickness and at least 1 × 2 km in size (Krejčíř, 1955; Dojčáková et al., 1967, 1968; Hudáček et al., 1976a,b). Brittle plateaus (table mountains) were cut through by a system of joints and fissures during the ongoing travertine deposition due to the plastic flysch substrate. The fissures became a place of mineral water discharge with a formation of subvertical veins and fissure ridges.

During the Pleistocene and Holocene, the brittle deformation connected with weathering, karstification, and erosion formed fissure systems especially parallel to the plateau margins. Significant cambering built steep marginal rock walls (up to 40 m

high), rock towns (Kamenný raj), gorges (Peklo), and finally block fields. In this way, large parts of the original mound and ridges were destroyed during 3 Ma. The travertines can contain brown speleothems in the form of veinlets and clusters (Fig. 2b). The typical travertine from the Dreveník is pure limestone, composed mainly of calcite (96–99 %; Krejčíř, 1955; Hudáček et al., 1976a,b).

Younger spring mounds and ridges occur in the vicinity of the Pliocene travertine. Pažica (Early Pleistocene), Sobotisko (Middle Pleistocene), and Sivá Brada (Holocene) were exposed to fewer karstification and destruction than Pliocene travertine forms (Ložek, 1964; Pivko & Vojtko, 2021).

The extracted Spiš travertine is a high-quality decorative natural stone with satisfactory physical-mechanical properties. Bulk density is 2360–2580 kg·m⁻³, total porosity 3–11 %, water absorption 0.6–3 %, and uniaxial compressive strength 58–119 MPa (Holzer et al., 2009; Ivan, 1943; Krejčíř, 1955; Dojčáková et al., 1967, 1968; Hudáček et al., 1976a,b).

3. METHODS

History of the block extraction and utilization of compacted Spiš travertine were reconstructed according to written sources, historical and current topographic maps, geological maps, aerial and lidar-derived images, field research of travertine facies, forms in old quarries, and on buildings with used travertines.

References in written sources pointed to old quarries, which were then found in historical and current maps and images, which capture short sections of the extraction history. The quarries were subsequently verified in the field by studying extraction methods and petrography. Subsequently, the rocks from the quarries were compared with the rocks in buildings and monuments. The petrography and provenance of buildings and monument study can also help in the selection of quarrying areas. According to the dating of stone buildings and monuments, the period of the quarry extraction was determined.

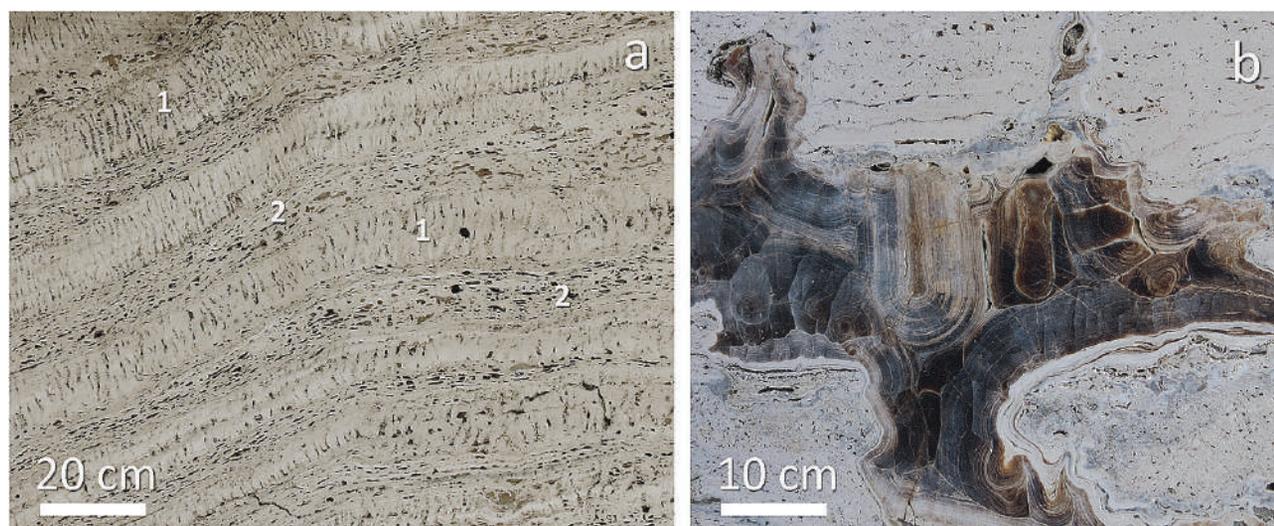


Fig. 2. Typical appearance of the Spiš travertine with alternated abigenic (1) and biogenic (2) layers on (a) image and brown speleothems cut travertine layers on (b).

Large-scale travertine forms are shown in the *geological map* (Gross et al., 1999). The *military maps* from the 18th and the 19th centuries (First Military Survey of Königreich Ungarn 1782–1785, Second military survey of the Habsburg Empire – Hungary 1819–1869, Third Military Survey of Habsburg Empire 1869–1887; Jankó & Porubská, 2013) satisfactorily display travertine forms and some quarries, a few already exhausted and abandoned. The maps are published online on *National Geoportal* (Národný geoportal, 2023), on *Arcanum – Maps of Europe* (Biszak & Biszak, 2023) or on *Staré Mapy* portal (Marek, 2023). During the First Czechoslovak Republic, the maps of the Third Military Survey were reambulated and derived Special maps 1:75,000 were processed up to 1938 (Zeman, 2012; Jakubík, 2012).

The territory of Slovakia was photographed from the air with a resolution of 0.5 m around 1949–1952 (Kardoš et al., 2017). The *images* are published online on the Historical Orthophotomap of Slovakia (*Historická ortofotomapa Slovenska*; Koreň, 2023). In the years 1952–1957, military topographic maps were compiled at a scale of 1:25,000 (TM 25). In 1955–1961, topographic mapping was carried out on only 10 % of the territory at a scale of 1:5,000 (TM 5) in economically important areas, partly in the studied area. In 1957–1971, mapping was started at a scale of 1:10,000 (TM 10). After 1971, map TM 10 was transformed into a new clade of basic maps 1:10,000 (ZM 10), which were photogrammetrically updated (Zeman, 2012). Military maps of 1:25,000 and 1:50,000 scales have been updated (RETM25, RETM50). The development of the Dreveník area, where travertine has been extracted in recent decades is well captured in aerial photography on orthophotomaps in 1985 and 2006, 2010, 2011, 2014 and 2016 to 2020 published online (Google EarthPro; Národný geoportal, 2023; Koreň, 2023). The digital elevation model DMR 5.0 of Slovakia created by airborne lidar is accessible online (Koreň, 2023; Mapový klient ZBGIS, 2023).

Field research was focused on the study of recent and fossil forms, their sedimentary facies and extraction forms. The fossil facies were observed macroscopically and by magnifying glass from 2× to 30×. The most studied sites were the Dreveník coalesced mound and the surrounding mounds. Travertine samples were studied by optical microscope and USB microscope Levenhuk with a 200× magnification. Many structures in travertines are very difficult to observe with the naked eye due to their very similar shade. If images were darkened and contrasted, many structures would become visible. Reviews of Slovak travertine forms and datings were performed in Pivko & Vojtko (2021), facies in Pivko (2021) and Slovak terminology in Pivko (2022).

The travertine stone products in a building's exterior or interior such as ashlars, architectural elements (vaulting elements, portals, window frames), cladding, flooring, and plastic products (statues, baptismal fonts, and tombstones) were investigated. The study about the use of Slovak travertine in history is based on the author's inspection of buildings and small architecture throughout Slovakia. Only a part of the obtained extensive data is used for the need of this paper. The Spiš travertine utilization is demonstrated on tombstones from Spišské Podhradie town, the nearest locality to the biggest Spiš travertine quarries. Supra-regional significance is illustrated in buildings and monuments in Bratislava, the capital of Slovakia.

4. RESULTS

4.1. Temporal development of block extraction according to maps and images

No quarries at the Dreveník and Ostrá hora hills are indicated on the maps of the 1st military survey (1769 and 1784; according to Jankó & Porubská, 2013). The edges of the triangular plateau of the Dreveník are highlighted as rocky and blocks occur below them only in the NW part. Smaller mounds with a sharp edge from the west were indicated NW of the Dreveník (Fig. 3a). Terrain edges and ravines occur in the SW part of Ostrá hora (Scharfen B.) on the map (Fig. 3b) of the 2nd military survey (1821; Jankó & Porubská, 2013). The probable quarries and the mark of a quarry in this area are marked on the map (Fig. 3c; No. 1 and 2) of the 3rd military survey (1876; Jankó & Porubská, 2013). A block field and the inscription *Vápenica* are indicated below the rock wall in the south of the Dreveník. Special map 1:75,000, on which the year 1938 is indicated for the Dreveník (1938; Marek, 2023), displays quarries with a road in the SW of Ostrá hora, a quarry in the NW of the Dreveník and as a new quarry (No. 4) in the SW part of the southern edge of the Dreveník (Fig. 3d).

The quarries can be distinguished on the black and white aerial images of 1949–1952 (Kardoš et al., 2017) according to the white colour, pointing to the absence of vegetation, the presence of fresh rock, and according to the white roads that were used and not overgrown. The aerial photographs exhibit 13 quarries, 1 on the W with a road (No. 5), 2 on the SW edge of Ostrá hora with 1 road (No. 1), 5 on the NW foot of the Dreveník with 1 main road (No. 2), 3 on the S edge of the Dreveník (No. 4, 6, 8) with 1 distinct road and 2 on the E edge of the Dreveník (No. 7, 9) with roads (Fig. 3e,f).

The situation is similar to the military TM25 from 1955 (Marek, 2023). A new quarry is displayed under the W edge of the Dreveník with the road (No. 10) and the quarry in the middle of the eastern edge of the Dreveník is not indicated on the map (No. 9), only its road (Fig. 3g). On the map TM5 from 1958 (Marek, 2023), which concerns only the easternmost part of the Dreveník, a quarry with heaps without a road is shown (No. 7). The map TM10 (Fig. 3h) from 1964 (Marek, 2023) displays 2 or 3 quarries with roads leading to Spišské Podhradie at the SW at the foot of Ostrá hora (No. 1) marked with *váp.* (limestone for lime production), the largest quarry in the NW foot of the Dreveník with a road and a railway marked with *trav.* (travertine) inscription (No. 2), a small quarry with a road on the W edge of the Dreveník with *trav.* (No. 10), 2 quarries with paths on the S edge of the Dreveník with *trav.* (No. 4, 6), and a quarry without a road on the SE edge of the Dreveník (No. 8).

The maps at scales of 1:50,000 (RETM50) and 1:10,000 (ZM10) come from the 1980s according to the existence of a quarry on the Dreveník (No. 11) and according to inscriptions corresponding to the socialist era. A new quarry (No. 11) with a road in the south of the Dreveník plateau and the connection of quarries between the W feet of Ostrá hora and the Dreveník are drawn on the maps (No. 1, 2). A similar situation is shown in the 1984 aerial image (Google EarthPro, 2022). Aerial images made between 2006 and 2021 (Google EarthPro, 2022; Národný

geoportal, 2023; Koreň, 2023) display quarries gradually overgrown by vegetation in the S part of the Dreveník (No. 4, 6, 8) and continued extraction in the system of quarries at the NW foot of the Dreveník (No. 1) with a peak in 2011. Today's state of the quarries is best visible on the lidar image (Fig. 4).

Small pit quarries were identified in Pažica (Fig. 3j-l) and Sobotisko (Fig. 3m-r) travertine mounds on the military map (1876; Jankó & Porubská, 2013), on the orthophotomap (ca. 1950; Koreň, 2023), and on the map 1:5,000 (1958, Marek,

2023). Lidar images (Mapový klient ZBGIS, 2023) recorded many shallow quarries at N and S of Pažica, at Sobotisko, and they were partly identified on the Spiš castle slopes (Fig. 3i), especially on the NE and SW sides.

4.2. Extraction methods

The oldest quarrying of the Spiš travertine can relate to the Spiš castle building in the 12th century (Kresánek, 2009). The



Fig. 3. The Spiš travertine extraction at the Dreveník (a-h), NW Dreveník (e), the Spiš castle (c-d, g-i), Pažica (j-l), and Sobotisko (m-r) on maps and images: a – First Military Survey of Königreich Ungarn 1782–1785, b, m – Second military survey of the Habsburg Empire – Hungary (1821), c, n – Third Military Survey of Habsburg Empire (1876), d – Special maps 1:75,000 (1930s), e-f, j, o – aerial images ca. 1950, g – military topographic maps 1:25,000 (TM25, 1952–1957), k, p – topographic map 1:5,000 (TM 5, 1955–1961), h – military maps 1:25,000 (RETM25, 1970s), and i, l, r – digital elevation model DMR 5.0 (Biszak & Biszak, 2023; Koreň, 2023; Marek, 2023, Národný Geoportál, 2023; Mapový klient ZBGIS, 2023; Jankó & Porubská, 2013). The red numbers on the pictures are in accordance with Fig. 4.

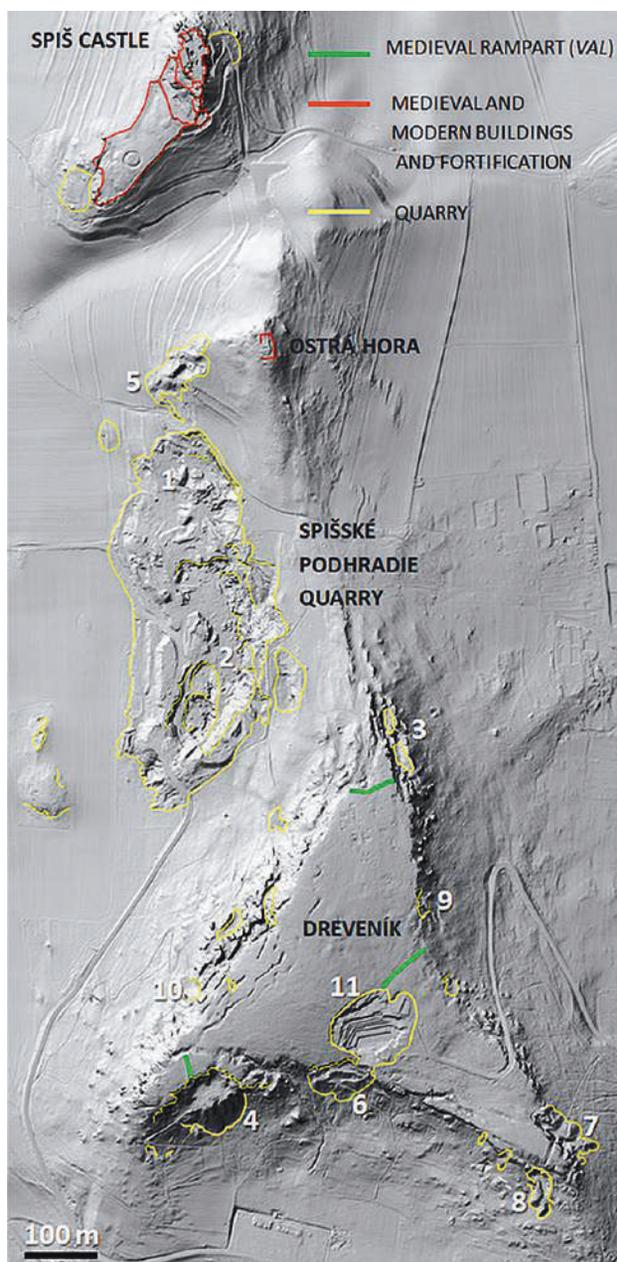


Fig. 4. Present-day LIDAR image of travertine mounds of Spiš travertine with quarries (numbers are following Fig. 3).

travertine was extracted over 7 centuries from pits and small quarries (Fig. 5). Large quarries were founded at the turn of the 19th and 20th centuries (Schafarzik, 1909) and their great development and expansion started between world wars (Ivan, 1941a,b, 1943) and was completed at the end of the 20th century (Fig. 6).

The extraction of travertine boulders was identified from block fields and rock avalanches (Fig. 5a,b). Irregular blocks were dug out and pulled out of regolith with the help of a lever over the centuries and by an excavator at the Spišské Podhradie quarry nowadays. Quarry faces were found on broken steep travertine walls (Fig. 5f,g). They could show irregular broken surfaces or almost flat joint surfaces. They are cut by regular or irregular joint systems and bedding planes (Figs. 5e-g,6c). Some joints are open.

The oldest hand-made tool marks are very rare and they are preserved only in the old quarry at the southern quarry face of Drevení hill (Fig. 4; No. 6). Flat surfaces can be covered by the *subparallel grooves* of tools (Fig. 7a,b). Only three *channels* covered with grooves (Fig. 7b–d) are presented being found along joints. The *channel walls* occur in a convergent shape. The channels are 30, 60, and 90 cm long, deep to a few cm, and wide up to 10 cm. One left cylindrical chisel was found in the joint of the Ostrá hora quarry (Fig. 7e).

Drilled cylindrical cross-sections of tens of cm in length occur on quarry faces (Fig. 4; No. 2, 6, and 11) as individuals (Fig. 7f) or frequently in subparallel sets (Fig. 7g-i), rarely as circular *holes* with diameter up to 4 cm (Fig. 7j). Circular holes or their perpendicular cylindrical cross-sections can be usually arranged to a *row* with spacing from several to ca. 20 cm (Fig. 7g-k).

Marks of sawing are visible in the most modern quarries from the second half of the 20th century. Extracted irregular blocks are dressed by diamond wire saw in the quarry near Spišské Podhradie (Fig. 8a–c; Fig. 4 No. 2). Very long vertical grooves after sawing up to 6 cm were observed in the most modern quarry near Žehra village (Fig. 8d; Fig. 4 No. 11). Some quarry faces with uneven broken surface contain the blasting holes with radiating joints (Fig. 8e).

Abandoned travertine blocks (Fig. 8f-i) or stored blocks (Fig. 8j) were found in disused quarries (Fig. 4 No. 2, 7, and 11) from the 20th century with sawing and drilling marks on the surface. Travertine blocks are processed to e.g., slabs (Fig. 8k).

4.3. Buildings, monuments, and tombstones

The Spiš travertine was identified on and in almost a thousand public buildings, monuments, and tombstones throughout Slovakia and abroad (Fig. 9). The utilization of the Spiš travertine is demonstrated on tombstones in Spišské Podhradie cemetery as the nearest locality to biggest quarries (Fig. 9k No. 1, 2). The exact dating of the tombstones is problematic because there are no documents. It is assumed that they arose shortly after death (Pivko & Sláviková, 2013). The chart (Fig. 10) outlines maximal tombstone production from ca. 1880 to 1950 with the peak ca. from 1900 to 1925. Supraregional significance of the Spiš travertine is demonstrated on public buildings and monuments of Bratislava, the capital of Slovakia (Fig. 9o–r,t–u). The age is based on catalogues (Kusý, 1976; Dulla & Moravčíková, 2002; Moravčíková et al., 2023), fewer architectural styles and similarities to known buildings. The chart in Fig. 10 presents the utilization of the Spiš travertine in Bratislava on buildings from ca. 1920 to 2020. The distribution peaks were at ca. 1930 to 1940, 1950 to 1955, and 1965 to 1975.

5. INTERPRETATION AND DISCUSSION

The chapter summarizes and discusses knowledge of the Spiš travertine block extraction from historical written records, maps, images, traces of the extraction and realizations, and arranges the findings in chronological order.

5.1. Preindustrial period from the 12th to the 13th centuries with a local significance

The oldest traces of human activity occur on the Dreveník and the Spiš Castle travertine mounds from the Neolithic and the

Eneolithic periods, the Bronze Age, and later the Púchov Culture of the Iron Age. The Spiš region was inhabited by Slavs at least since the 8th century, which left ramparts on the Dreveník. The first important constructions from the Spiš travertine occur at the Spiš castle, built on a travertine coalesced mound. The



Fig. 5. Former small Spiš travertine quarries: a – extracted travertine towers from block field at the Dreveník (Kamenný raj, quarry No. 3), b – an extraction from block field with weathered raw blocks of travertine in terra rossa soil and speleothems (No. 2), c – shallow quarries at Sobotisko site, d – a quarry at Ostrá hora site (No. 5), e – a quarry with debris on the Dreveník top, f – a quarry at southern slope of the Dreveník, g – a quarry with heaps at southern slope of the Dreveník (No. 4), and h – Pažica quarry with Spišská Kapitula and Spiš castle in the background (Thomas Ender 1861–1863).

fortified castle with a stone tower probably comes from the 1st half of the 12th century (Slivka, 2003; Soják, 2009; Repka, 2011; Horváthová & Soják, 2012; Soják & Fecko, 2015). First builders

used broken travertines. The tower, which does not exist today, could also contain worked travertine.

A Romanesque castle with dressed travertine ashlars and fine



Fig. 6. Spiš travertine quarries with the block extraction on NW of the Dreveník slope (a-f, Fig. 4, No. 2) and S part of the Dreveník (g-j, Fig. 4, No. 11): a – large active quarry near Spišské Podhradie, b – steep inclined weathered travertine beds in an abandoned part of the quarry, c – significantly cracked quarry faces, d – travertine debris heap coloured by terra rossa soil with the Spiš castle in the background, e-f – the active part of the quarry with blocks and crushed aggregate production, g-h – the most modern quarry closed in 1990s, and i-j – former block extraction by chain saw in stepped quarry.



Fig. 7. Marks of extraction methods used on the Spiš travertine quarry faces. a – subparallel marks, b – subparallel marks and a channel for wedges along joint, c – channel for wedge along joint, d – channel for wedge along joint and drill mark, e – chisel inside joint, f – lateral marks of vertical borehole, g-i – lateral marks of a set of vertical boreholes, j – a set of vertical boreholes, and k – a set of vertical boreholes on travertine block.

architectonic elements as capitals of columns was built in the 13th century, which was in Slovak territory during a period of construction boom. Similar architectural elements and ashlars were used in the Romanesque churches in Spišská Kapitula, Spišské Podhradie, Spišské Vlachy, and Spišský Štiavnik (Plaček & Bóna, 2007; Kresánek, 2009; Buran et al., 2003; Pomfyová, 2003).

The question is why the Spiš travertine was extensively used for fine-dressed products in the 13th century. The answer is related to increasing immigration in the 12th and 13th centuries from the Romance and the German regions of the German kingdom to the Spiš region. In the half of the 12th century, Walloon immigrants from today's Eastern Belgium (Liège surroundings)



Fig. 8. Extraction methods of the Spiš travertine blocks. a-b – blocks formed by diamond wire saw, c – diamond wire on travertine, d – chain saw edge and groove, e – radiating joints originated from the explosion point, f-g – abandoned travertine blocks, h-i – abandoned travertine blocks with drilled and sawed surface, j – travertine block storage with sawed and drilled surfaces, and k – travertine slabs with marks of drilling on edges.

settled in Spišské Vlachy, 6 km south of the Spiš castle. Their close neighbors Germans (Flemish?) from the Nordrhein region

who came at the end of the 12th century. The construction skill of Walloons or French stonemasons was widely known and



Fig. 9. The Spiš travertine realizations: a, d, g – Romanesque cathedral in Spišská Kapitula (the 13th century), b, c, e – Romanesque architecture on the Spiš castle (the 13th century), h – Romanesque tower of Spišské Podhradie church with Gothic portal (the 14th century), i–k – tombstones (i – in Spišské Podhradie of the 13th century, j – in Spišská Kapitula of the 17th century, k – Spišské Podhradie of the 1880s), l – reconstructed Marian column in Spišská Nová Ves (the 2nd half of the 19th century), m – theatre in Spišská Nová Ves (1905), n – *Štefánik* barrow in Priepeasné – Bradlo (1928), o – Slovak National Museum in Bratislava (1928), p – General Prosecutor's Office in Bratislava (1938), r – church in Bratislava – Lamač (1950), s – war memorial in Košický Kečenov (1955), t – ballustrade on the Danube embankment in Bratislava (1954–1958), u – Slovak National Theatre in Bratislava (2005), and v – Constantine the Philosopher University in Nitra (after 2000).

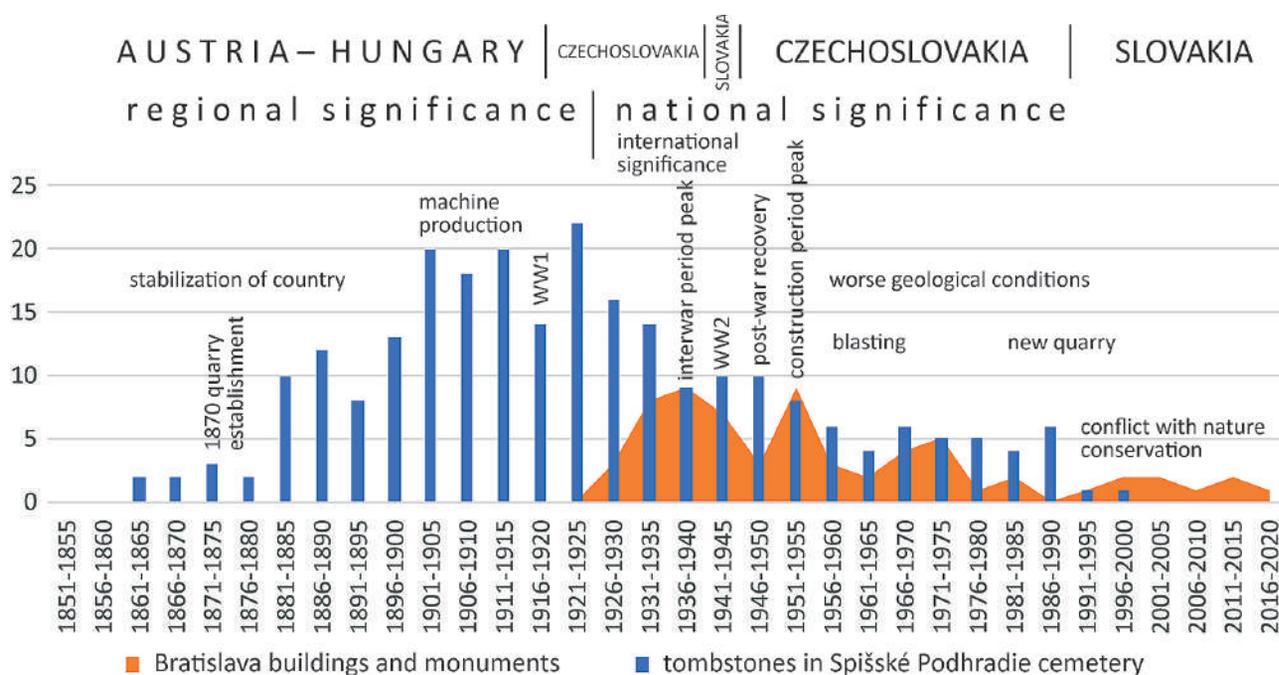


Fig. 10. The boom-and-bust cycles of the Spiš travertine extraction according to travertine realizations during the 2nd half of the 19th, 20th, and 21st centuries, and historical events.

often used in medieval Hungary (Marek, 2006; Števík, 2009). The Wallons and the Germans from the Rhein came from craft-developed areas of the German realm. The local stonemasons had extensive experience in processing the Paleozoic limestone (Ardennes). In the Spiš region, they could use their skills in working with travertines.

5.2. Period of sporadic block production from the 14th century to the 1860s

From the 14th to the middle of the 19th century, the Spiš travertine blocks were used very rarely, only in the immediate vicinity. In the Spiš region, flysch sandstones were preferred compared to travertines for dressed products due to their better processing (workability). An excellent example is the chapel in the Spiš Castle from the 15th century constructed on a travertine mound with architectural sandstone and no travertine elements (Kresánek, 2009).

From the middle of the 13th century, after the Mongol invasion, numerous German immigrants from Saxony came and settled in Spišské Podhradie, directly below the Spiš Castle. The Saxons colonization in the second half of the 13th century outnumbered the Wallons and the earlier German colonization (Marek, 2006; Števík, 2009). They probably brought skill in sandstone processing due to sandstones as workable stones in their original homeland.

The Spiš travertine blocks were quarried during the Middle Ages by an extraction of boulders from block fields, and possibly from weathered travertine steep outcrops with abundant vertical fissures and bedding planes to which levers were inserted. Former quarries on the Spiš Castle travertine mound were covered by buildings. Possible quarries could occur on SW of Ostrá hora, where steep travertine walls with marked blocks below them

(Fig. 3a,b) are recorded on military maps from the 2nd half of the 18th and the 1st half of the 19th centuries (Biszak & Biszak, 2023). Broken Spiš travertine was used as a building material and for lime production.

From the 4th quarter of the 17th to the beginning of the 18th century, tombstones made of the Spiš travertine occurred near Spišská Kapitula and Spišské Podhradie. It was in an unstable period during the anti-Habsburg uprisings of Tököly and Rákóczy. Travertine tombstones were an exception because they were made usually from flysch sandstone, e.g., collection in the Evangelical church in Kežmarok since 1688 (Dudáš, 2011).

5.3. Preindustrial to industrial period from the 1860s to 1918 with regional significance

In the 2nd half of the 19th century, the industrial revolution occurred in the Austria-Hungary. Suitable economic conditions were supported by a peaceful period and state interventions in the economy such as cheap loans, subsidies, tax exemptions, trade laws, and chambers (Hlavačka et al., 2010). The Spiš travertine importance started to rise around 1860 when travertine tombstones appeared again. Their production increased through the 1970s to a greater extent from the 1880s with a maximum before World War I (Fig. 10). Similarly, the rapid growth of tombstones was reflected in the National Cemetery in Martin since the 1870s, when the production of typed industrial tombstones from Silesian marble appeared (Pivko & Sláviková, 2013).

The development in the Spiš travertine production is additionally related to the arrival of Northern Italian stonemasons (Varese, Lombardia) from the Miglierini family to the construction of the Košice-Bohumín railway (1867–1872), where they participated in the building of the bridges and tunnels (Királ'et

al., 2016; Bevilaqua, 2014). They bought the travertine quarry in Gánovce close to the railway in 1875 (Schafarzík, 1909). Other Italian stonemasons arrived in the 1880s, when they obtained new stonemasonry orders (Bevilaqua, 2014), e.g., roadside crosses and tombstones which is related to the growth of upper- and middle-class wealth.

The Miglierini family rented a quarry at the Dreveník from Countess Csáky of Hodkovce in 1896. Italian stonemasons were settled at Spišské Vlchy – Dobrá Voľa below S slopes of the Dreveník and at Spišské Podhradie, SW of the Dreveník (Soják, 2021; Királ et al. 2016, Bevilaqua 2014, 2021). Italians gained experience with carbonate rock processing due to the similar geology in their native country.

Possible quarries suitable for the block extraction can be indicated on the W side of Ostrá hora and NW of the Dreveník hills (the 3rd Military Survey from 1876; Biszak & Biszak, 2023), which is consistent with Schafarzík (1909), who has written about municipal quarry on SW of the Ostrá hora, that was extracted since the 19th century. The rock was broken in an average of 0.5 m blocks and 300 m³ was quarried annually. Travertine was used as a raw and worked building stone and for lime. Schafarzík (1909) also mentioned the quarry near Spišská Kapitula on NW of the Dreveník since ‘ancient times’ with a foundation of a real quarry from 1870 for blocks, lime, and crushed stone for roads. The extraction continued to grow. S side of the Dreveník suggests extraction for lime production according to an inscription on the map of the 3rd Military Survey (Biszak & Biszak, 2023). Schafarzík (1909) described an extraction for lime at the NE side of the Dreveník near Hodkovce. The quarry was rented from Count Kálmán Csáky to Johann Koritkó. Austrian landscape painter Thomas Ender displayed old quarries on Pažica mound (Fig. 3h) and possibly on Ostrá hora and NW of the Dreveník (1861–1863; Rozsondai et al., 2000).

Italian stonemason probably used classical extraction methods partly visible in the quarry faces on S of the Dreveník (Fig. 5h). They used vertical and horizontal natural joints. The open joints (fissures) had to be enlarged by force, which means that a stone block bounded by the joints could be broken off. If the joint was closed, it was necessary to open it at least in one part for a lever. Into the selected joint, the channel was carved with a chisel (Fig. 7c,d), where wedges were inserted. Then the stone block was separated by gradual hitting with a hammer on the wedges. If a wider joint was naturally present in the quarry or it was formed by the wedges, then a lever was inserted into it in the form of a long iron lever or crowbar (Pivko, 2018). They later used vertical drilling of tens of cm in length, recording as circular holes with a diameter of up to 4 cm.

Italian stonemasons came initially to Slovakia seasonally, from spring to late autumn. They drilled vertical holes with larger diameters into travertine in a line about 1 foot apart before winter. They paid a local man to pour water into the holes during the winter, and so when they returned in the spring, thanks to the frost, they obtained broken blocks of travertine from a quarry face, suitable for following processing (Soják, 2021). It is assumed that machine drilling in the quarries began to be used in our country at the end of the 19th century, just as it was in the mines since 1873 (Gindl, 1971; Magula, 1971).

Dressed travertine products such as construction stones, statues, sculptures, and paving supplied the Spiš county, but reached Košice, Rožňava, and Budapest (Schafarzík, 1909). Examples of public realizations from this period are Immaculata column renovations, some schools, and the theatre building in Spišská Nová Ves.

5.4. Industrial period from 1919 to 1939 with national and international importance

After World War I, most Italians returned to Italy and some of them continued to work (Bevilaqua, 2014) probably on S and E of the Dreveník slopes. Landowners Csáky and Spišská Kapitula leased quarries on the Dreveník and Ostrá hora to the companies of Marco Miglierini, Polay, and Inž. B. Minařů from Košice in the 1920s (Kubíček, 1929). Miglierini, Škvára, Cingroš, and Grünapfel used the quarries in the 1930s (Hájek, 1935; Šefčáková, 2007; Kormošová, 2008; Stockmann, 2009).

Five technically equipped quarries and two smaller quarries worked in the Dreveník area (Ivan, 1941a). According to the map (1938, Marek 2012–2023), larger equipped quarries with roads were situated SW of the Ostrá hora, two NW of the Dreveník, SW of the Dreveník, and without road SE of the Dreveník.

The extraction was finished around 1926 in the rock town Kamenný raj by Miglierini company due to nature preservation (Stockmann, 2009). Three quarries on S of the Dreveník slopes were abandoned during the economic crisis Great Depression in 1929–1933 (Hudáček et al., 1976a). The discrepancy between the closure of quarries during the economic crisis (Hudáček et al., 1976a) and the extraction in 7 quarries (Ivan, 1941a) can be explained due to the break in the extraction of several quarries because of the crisis. A stone extraction on Pažica and Sobotisko is not displayed in the map (1938, Marek 2012–2023) but is expected only for local building purposes in shallow pits.

Travertine blocks were extracted by vertical drilling and wedging in technically equipped quarries and probably by levering and wedging in smaller quarries. According to Šefčáková (2007), blasting was used in the Ostrá hora quarry. The amount of excavated material is little known. A quarry in S of the Dreveník quarried about 70,000 m³ of travertine (Hudáček et al., 1976a). Miglierini’s stone company extracted and processed 7,000 Spiš travertine blocks for the construction of the Štefánik monument in 1928, transported in almost 200 train wagons (Bevilaqua, 2021).

Industrial quarrying began after the establishment of a cutting device for natural blocks in stonemason workshops. High-quality travertine was processed by modern machinery for stone cutting with steel saws and quartz sand, grinding, and polishing, powered by electric motors in Spišské Vlchy (Vinduška company), Krompachy (Ing. Minarů company), and Spišské Podhradie workshops (Miglierini company). They worked out the products under the name ‘Spiš travertine’ for cladding, monuments, tombstones, stair treads, landmarks, paving, building blocks, etc. Travertine tailings were used for lime production (Ivan, 1941a, 1943; Hudáček et al., 1976; Stupák et al., 1993; Királ et al., 2016).

The Spiš travertine soon became a fashionable facing stone after the production of polished tiles (Hudáček et al., 1976a,b). Spiš travertine reached Czechia in 1919 or 1920, shortly after the Czechoslovakia established. The quarries in the Dreveník supplied white travertine through United Prague factories for building materials (Spojené pražské továrny na staviva), Gabriel, Förster, Vinduška, and Miglierini companies to several buildings in Czechia and the Subcarpathian Rus', e.g., buildings of ministries in Prague, Faculty of Law, Masaryk University in Brno, Police building in Ostrava, and Užhorod. The most extensive realization is the construction of the Štefánik monument (Štefánikova mohyla) on Bradlo hill (Kubíček, 1929; Vinduška and Förster company advertising in Kubíček, 1929; Hájek, 1935; Bevilacqua, 2021). This huge project was a great impetus for the spread of the Spiš travertine throughout Slovakia, to almost all Slovak cities and towns, especially to the capital city Bratislava. The large volume of the Spiš travertine was used e.g., on administrative buildings in Bratislava, Košice, churches in Bratislava and Žilina. The Spiš travertine appeared before 1938 in France, the Netherlands, Belgium, Germany, England, America, and Australia (Ivan, 1941a,b, 1943).

The great development of the extraction, processing, and use of the Spiš travertine is evident from the graph with summarized travertine realization in Bratislava (Fig. 10), where the peak is before World War II, ca. 1930 to 1940. The graph of Spišské Podhradie tombstone usage (Fig. 10) demonstrates the greatest development of tombstones after World War I but with a rapid decline up to World War II. The decrease was probably caused by the importation of cheaper tombstones from Czech countries, e.g., Hořice sandstone and Silesian marble (Pivko & Sláviková, 2013; Pivko, 2019).

5.5. Industrial period between 1940 and 1989 with national significance

During World War II, the Spiš travertine was processed by Vinduška Spišské Vlchy and Minařů Krompachy (Ivan, 1941a,b, 1943). The travertine was used in dozens of Slovak cities when Slovakia was a legally independent state. An aerial photo taken around 1950 (Koreň, 2023; Fig. 3e,f) confirms similar situation as was documented by Ivan (1941a,b, 1943), namely 2 quarries with roads on Ostrá hora, ca. 5 quarries with roads on NW of the Dreveník, 2 quarries with roads on SE of the Dreveník, 1 quarry with road on SW, S, and E of the Dreveník. The image records the largest number of quarries (12) in known history, which can be explained by the construction boom after World War II. Travertines for building purposes were also extracted on Pažica and Sobotisko hills, what is visible on the aerial image (ca. 1950; Koreň, 2023; Fig. 3j,o) and maps (1950s; Marek, 2023; Fig. 3). Žilina and Ružomberok town centres belong to the towns with the biggest travertine realizations during the Slovak state.

After World War II, Czechoslovakia was restored in 1945 and many travertine war memorials were constructed. Since 1948, the new communist state needed decorative stone for many administrative buildings and monuments. A cutting machine in Spišské Vlchy by the Vinduška company was renovated

(Hudáček et al., 1976a,b; Pivko, 2007). Between 1945 and 1950, the quarries and workshops gradually passed into the ownership of the state. Grünapfel became the national administrator of his former quarry on Ostrá hora for a short time after 1945 (Šefčáková, 2007).

In 1955, a continual extraction was already taking place only in a large quarry on NW of the Dreveník composed of tree-closed individual quarries. The triple quarry near Spišské Podhradie belonging up to 1958 to the Východoslovenské kameňolomy n.p., Prešov company (Eastern Slovak quarries, national enterprise) and after 1958 to the Východoslovenské nerudné bane a kameňolomy n.p. company (Eastern Slovak non-metallic mines and quarries), Spišská Nová Ves (Krejčíř, 1955; Dojčáková et al., 1967). Occasional quarrying of blocks (inscription *trav.*) or material for lime (inscription *lime*) occurred in other older quarries on Ostrá hora, in the south of Dreveník, according to the roads on maps in the 1950s and 1960s. The small new quarry was founded in the forest on the W slope of the Dreveník, 250 m SW from the elevation of the Dreveník. In the 1950s, a road led from the quarry to the United Peasant Cooperative, which apparently used the excavated stone as building stone (map 1:25,000; Marek, 2023).

In the 1950s, the work in the Spišské Podhradie quarry occurred at a very low level. The blocks and stone products were processed by hand. Block production performs only 10 % of the total extraction (12,000 m³). Most of it was used for road stone (42 %) and lime kiln (25 %) at the Spišské Podhradie railway station. The rest was processed to smaller stonemason products (23 %). Transport in the quarry provided a narrow-gauge diesel locomotive. The blocks of travertine were transported from the quarry to the railway station and from there for further processing to machine cutting, grinding, and polishing in Spišské Vlchy and Krompachy workshops. Irregular cracking of the deposit caused a low yield of blocks (Krejčíř, 1955; Hájek & Kroupa, 1964; Dojčáková et al., 1967). The extraction of travertine was threatened by a conflict of interests, since the Dreveník was declared a national nature reserve in 1953, nevertheless, without defined borders (Stupák et al., 1993). Despite the primitive extraction, Spiš travertine was widely used throughout Czechoslovakia in the 1950s, especially in Slovak cities with the peak between 1950 and 1955 (Fig. 10). Examples with a large travertine volume are memorials in Dargov, Svidník, Zvolen, and Jankov vršok, a building of Slovak Technical University in Bratislava, balustrade along Danube river in Bratislava, and housing estate in Žilina.

In the 1960s, the Spiš travertine was extracted by the Slovenský priemysel kameňa (Slovak stone industry company), Levice in 3 connected quarries with quarry faces heights from 8 up to 40 m. The travertine was extracted by pneumatic drilling and blasting which significantly increased production (Fig. 11), but adverse geological conditions and inappropriate blasting damaged the raw material and reduced the block production from 10 % (1954) over 6.5 % (1960) to 2 % (1965). The raw blocks were processed in the Spišské Vlchy and Krompachy workshops or were loaded onto train wagons for external customers. Travertine unsuitable for large blocks was processed manually or partly by pneumatic machines for smaller stone products

(2 %) as kerbs, stairs, stone measuring marks, boundary stones, verge posts, balusters, ashlar ('kopák' and 'haklík' in Slovak and Czech), or was used as quarry stone, and crushed stone (18–25 %), and for lime (Hájek & Kroupa, 1964; Dojčáková et al., 1967, 1968; Hudáček et al., 1976a,b). The decrease of the block production (1200 m³ in 1954, 870 m³ in 1960, and 600 m³ in 1966; Krejčíř, 1955; Hájek & Kroupa, 1964; Dojčáková et al., 1967, 1968) is also reflected in the use on buildings in Bratislava (Fig. 10).

Between 1967 and 1975, the Spišské Podhradie quarry produced 2 % of blocks, 11 % of smaller stone products (like ash-lars), 19 % of quarry stone, and the rest as waste for heaps. The blocks were processed in Spišské Vlchy and Spišské Podhradie. Increasing extraction from 33,200 to 55,000 m³ during constant block production (Hájek & Kroupa, 1964; Dojčáková et al., 1967, 1968; Hudáček et al., 1976a,b) ensured demand for travertine products, which is visible in the graph of realizations in Bratislava with peak from 1965 to 1975 (Fig. 10). Between 1960 and 1975, important public buildings were constructed with the use of the Spiš travertine, e.g., cultural houses, management offices, hotels (High Tatras, Bratislava), and supermarket Prior in Bratislava.

A low block yield in the Spišské Podhradie quarry led to a geological survey of the new Žehra deposit on the S part of Dreveník hill in 1976, which was paradoxically situated at a nature reserve. The survey found a travertine reserve of 2.6 million m³ with a very favorable block yield of up to 69 % and the possibility of using cutting machines along the quarry face and releasing the blocks with hydraulic wedges from the bottom. The Žehra deposit was opened between 1980 and 1983. Experimental extraction did not yield the expected results. The travertine blocks accounted for only 1 % due to blasting and the extraction of a weathered zone (Hudáček et al., 1976a,b; Hudáček, 1985). Even though the Dreveník was declared a state nature reserve in 1982 with a defined area, Kameňopriemysel

(Stone industry company) Levice as a state enterprise asked the Ministry of Culture of the Slovak Republic for an exemption and continued quarrying near Spišské Podhradie and Žehra (Začková, 2001). Compared to the project, the quarrying in Žehra was moved further south to worse geological conditions. Bulgarian chain saw system has been used since 1985 and 31,000 m³ of travertine has been extracted since the quarry foundation. The start-up to full operation was until 1988–1989 (Hudáček, 1985; Stupák et al., 1993).

The decrease in the Spiš travertine production is documented in reports from 55,000 m³ (1975) to 22,000 m³ (1988) and data are graphically presented in Figs. 10 and 11. A deficiency of the Spiš travertine in the market was partly replaced after 1975 by light travertine from the Vyšné Ružbachy and light limestones from Bulgaria and the former Yugoslavia.

5.6. Block quarrying reduction from 1990

With the establishment of a democratic Czecho-Slovak Republic (1990) and subsequently Slovak Republic (1993), markets were opened for cheap decorative stones from India, Brazil, South Africa, and China through processors in Italy. Additionally, the production of Slovak decorative stones was reduced due to uncontrolled privatization and a conflict of interest with nature protection. The quarrying area of the Spišské Podhradie and Žehra deposits was diminished in 1991 (Stupák et al., 1993). The Dreveník was declared a national nature reserve in 1993 (Marek, 2009). The Slovak Environment Commission decided to abolish the Žehra quarrying area by the end of 1996 (Začková, 2001). Occasional quarrying continued in the big quarry on the SW slope of the Dreveník near Spišské Podhradie (Korpel, 1993). Kameňopriemysel Spiš a. s. has become the owner of quarries near Spišské Podhradie since 1995. The graph shows the overall decline in the extraction after 2000 (Fig. 11).

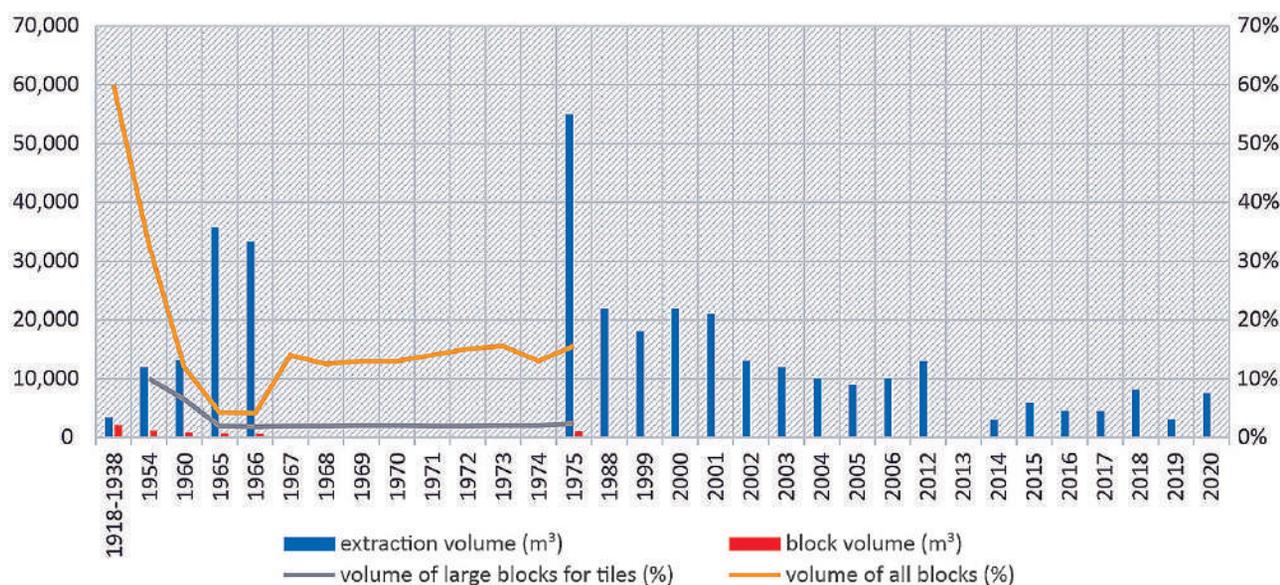


Fig. 11. The Spiš travertine extraction in the 20th and 21st centuries according to Krejčíř (1955), Hájek & Kroupa (1964), Dojčáková et al. (1967, 1968), Hudáček et al. (1976a,b), Tréger & Baláž (1998), Tréger et al. (1999), Tréger et al. (2000), Tréger et al. (2001), Baláž & Tréger (2002, 2003), Baláž (2004), Bauer & Žiaran (2005), Baláž & Kúšik (2005, 2006, 2007, 2013, 2015), Baláž et al. (2014), Kúšik et al. (2017, 2018, 2019), Soltés et al. (2020, 2021, 2022).

The Euro Kameň Ltd. company (Euro Kameň, 2023) replaced the original owner in 2005, nevertheless, mismanagement of the quarrying continued up to the collapse between 2011 and 2014 (Fig. 11). Forced restructuring and effective advertising of the company led to a revival of the production in 2014 (Lemešani, 2014). Unregular shaped blocks up to 2 m are extracted by an excavator from block fields and weathered travertine bodies. The blocks are formed by a diamond wire saw with a diameter of ca. 1 cm and they are subsequently processed in their workshop to tiles, flooring, cladding, staircases, architectural elements, luxury products like tables, and fountains with tiles enriched by onyx marble. The travertine products receive cemented, polished, grinded, brushed, and bush-hammered finishes.

6. CONCLUSION

The most used Slovak natural decorative stone was the whitish Spiš travertine, extracted during almost 9 centuries from the greatest travertine mounds in Slovakia of the Pliocene epoch. The analysis of written sources, historical and current topographic maps, geological maps, aerial and lidar-derived images, and field research of travertine facies, forms, old quarries, and buildings with used travertines enabled to define periods of the development of travertine block extraction and utilization.

1. *Preindustrial period from the 12th century to the 13th century with local significance.* The Spiš travertine was extracted from block fields for the Romanesque Spiš Castle construction. The Walloon and German immigrants from the Nordrhein region were able to dress a local travertine to fine architectural elements for the castle and nearby churches.

2. *Period of sporadic block production from the 14th century to the 1860s.* The Spiš travertine block was used very rarely. The stone was utilized as a building material and for lime production.

3. *Preindustrial to industrial period from the 1860s to 1918 with regional significance.* The growth of the Spiš travertine production is related to the Industrial Revolution with suitable economic conditions in the 2nd half of the 19th century and the arrival of Northern Italian stonemasons. They utilized levers, chisels, hammers, and at the end of the 19th century additionally machine drilling.

4. *Industrial period from 1919 to 1939 with national and international importance.* The emergence of a new Czechoslovakia state opened new markets. High-quality travertine was processed by modern electric machinery for stone cutting grinding and polishing. The Spiš travertine became a fashionable facing stone with the peak in the 1930s and was used in almost all Slovak cities and towns, additionally in Czech cities, and was exported to many European countries.

5. *Industrial period from 1940 to 1989 with national significance.* From 1940–1950, the Spiš travertine was used in dozens of Slovak cities with the largest number of active quarries. In the 1950s, continual quarrying was already taking place only in a large quarry near Spišské Podhradie. The Spiš travertine was widely used especially in Slovak cities for representative buildings and monuments. Total extraction of the Spiš travertine decreased,

although a new quarry was opened at the Žehra deposit with a chain saw system in the 1980s.

6. *Block quarrying reduction from 1990.* With the establishment of the democratic Czecho-Slovak Republic and subsequently Slovak Republic (1993), markets were opened for cheap natural stones from developing countries. Production of domestic stones was reduced due to uncontrolled privatization and a conflict of interests with nature protection. Reduced quarrying continues in present-day in Spišské Podhradie.

The Spiš Castle built on the travertine mound, Spišská Kapitula, Žehra, and Spišské Podhradie with their architecture was inscribed to the World Heritage List UNESCO in 1993. Substantial monuments are built from the Spiš travertine. I suggest special protection for the Spiš travertine due to the most important natural stone in Slovakia. The Drevení travertine plateau and the Spiš travertine should be added as a natural heritage to the UNESCO list.

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