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ORIGINAL ARTICLE

Geo-Cultural Aspects of Building Stone Extracted Within Brno City (Czech Republic): a Bridge Between Natural and Cultural Heritage

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Abstract
Building stone, its deposits, its extraction, and its use represents an element that may be considered a bridge between cultural and natural heritage of a given area. The research on building materials includes numerous aspects such as geological and geomorphological settings of the deposits, cultural aspects, overlaps with geoconservation efforts and urban geotourism development. The case study from Brno (Czech Republic) presents examples of building stones used in the city with an emphasis on Crinoidea Limestone and Old Red Conglomerate and Sandstone. These materials have been extracted since Middle Ages and they have left an imprint in the identity and look of the city. Both extraction sites and building stones present several mutually interconnected aspects, including the specifics of the deposits, history of mining, use of the stone in architecture, its importance within archaeological and historical research, its reflection in toponyms, the importance of old quarries (landforms) for geoconservation and their role in urban development. Based on the research and assessment of extraction sites, geotourist and geoeducational activities are designed with an emphasis on the complex promotion of natural and cultural heritage. Proposals for the activities which could be available even during the times of social distancing are also outlined.

Keywords Building stone · Crinoidea Limestone · Old Red Sandstone and Conglomerate · Geotourism · Geoeducation · Heritage

Introduction

Heritage is a broad concept, which includes the natural as well as the cultural environment and it encompasses landscapes, historic places, sites and built environments, as well as biodiversity, collections, past and continuing cultural practises, knowledge, and living experiences (ICOMOS 1999). The integrated view on heritage (natural heritage, respectively geoheritage and cultural heritage) and its conservation and promotion is currently emphasised by numerous authors (Coratza et al. 2016; Goemaere et al. 2016; Reynard and Giusti 2018; Gordon 2018; Boukhchim et al. 2018; Scarlett and Reide 2019). Within geotourism activities, this approach is usual as it helps to understand the relationships between different elements of the landscape and complexity of an area (Dowling and Newsome 2018; Gordon 2018). A holistic view on landscape and heritage significantly contributes to the acceptance of the conservation needs and sustainable management of specific heritage sites and objects (ICOMOS 1999; Larwood et al, 2017; Gordon 2018).

On the international level, first concepts of heritage which emphasised the conservation aspects appeared in the 1960s in The Venice Charter for the Conservation and Restoration of Monuments and Sites (ICOMOS 1964), but they were rather monument-oriented and focused on cultural heritage. In 1972, UNESCO presented the Convention concerning the protection of the world cultural and natural heritage, where both types of heritage are defined (UNESCO 1972). Generally, cultural heritage is defined as "an expression of the ways of living developed by a community and passed from generation to generation including customs, practises, objects, artistic expressions, and values" (ICOMOS 2002). Geoheritage, according to Dingwall (2005),

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is defined as those components of natural geodiversity of significant value to humans, including scientific research, education, aesthetics and inspiration, cultural development, and a sense of place experienced by communities. So-called mixed heritage is defined in Operational Guidelines for the Implementation of the World Heritage Convention (UNESCO 2017) as "properties that satisfy a part or the whole of the definitions of both cultural and natural heritage laid out in Articles 1 and 2 of the Convention".

Concerning geotourism development, the current approach also emphasises this multidisciplinarity, which is reflected both in the Arouca Declaration (2011) and recent definitions of geotourism (e.g., Martini et al. 2012; Dowling and Newsome 2018). It is generally assumed that mutual relationship can bring more understanding and acceptance of conservation proposals and generally, more appreciation of the landscape (Gordon 2018). Larwood et al, 2017) consider the connections between culture and nature complex and profound and present evidences based on the case studies why the understanding and protection of cultural and natural heritage should be approached in an integrated way.

Building stone, its deposits and its use in local and regional architecture (or cultural heritage) can represent such a bridge between natural and cultural heritage. The heritage importance of building stones has been already recognised (Bennett et al., 1996; De Wever et al. 2017; Brocx and Semeniuk 2019; Pereira and Van den Eynde, 2019) and the role of the building stones in geotourism and geoeducation especially in urban areas has been supported by numerous papers (e.g., Robinson 1982; Liccardo et al. 2012; Palacio-Prieto 2015; Reynard et al. 2017; Del Lama 2019). Thus, the importance of building stones in heritage protection, geotourism and geoeducation is indisputable and an integrative view on geology, geomorphology, history, and architecture is desirable for developing geoeducational and geotourist activities with respect to heritage values and geoconservation (Corbí et al. 2019). The research on building stone has also links to the research in the domains of history and archaeology (Bonomo et al. 2019; Marengo et al., 2019), as it allows the dating of the buildings, their construction phases and general placement in a space–time framework.

Thus, based on the abovementioned, importance of research on building stone can be summarised as follows:

1) as it focuses on the geological and geomorphological settings of the deposits or extraction sites, the history of mining and human influence on the relief and landscape in general, it can be seen as one of the bases for geoconservation efforts (Prosser 2019),
2) some stones or geo-materials are related to the regional identity or they are of great importance for heraldry (Gordon 2018; da Silva 2019),
3) use of local building stone in architecture and construction enables both locals and visitors to look at the monuments and other objects (simple buildings, walls, pavement) from a different point of view and helps to raise awareness about geoheritage and cultural heritage (Kubalíková et al. 2020; Baucon et al. 2020),
4) tracing the use of building stones on different buildings contributes to historical knowledge (Bonomo et al. 2019; Marengo et al., 2019),
5) building stone itself and extraction sites—quarries, pits, and mines (including the history and way of extraction) may represent an inseparable part of the urban heritage or a bridge between natural and cultural heritage and it serves as an excellent resource for geotourism and geoeducation (Robinson 1982; Pica et al. 2018; Gajek et al. 2019; Polck et al. 2020)

The case study from Brno (Czech Republic) presents examples of building stones used in the city with an emphasis on Crinoidea Limestone and Old Red Conglomerate and Sandstone. It proves that building stone should be considered a bridge between natural and cultural heritage as it presents numerous mutually interconnected aspects, including the specifics of the deposits and extraction sites, geoconservation aspects, history of mining, use of the stone in architecture, its importance within archaeological and historical research, its reflection in toponyms, the role of the quarries in urban development (e.g. emergency colonies—groups of unofficially built small houses inhabited especially by workers situated e.g. in abandoned quarries), and last but not least, the role of the stone in the identity of the city. Based on the research and evaluation of selected extraction sites, geotourist and geoeducational activities are designed with an emphasis on the complex promotion of natural and cultural heritage. Proposals for the activities which could be available even during the times of social distancing are also outlined.

Methods

The research on geotourism and geoeducational use of building stone in Brno is based on the multidisciplinary approach. It combines the Earth-science research (literature and map review, fieldwork, site-oriented research, and assessment of the sites) with humanities (e.g. history, archaeology) research (a detailed study of archives, literature, historical documents, analysis of old illustrations and photos). To a limited extent, the outcomes of technical methods are used as well (especially concerning the use of building stone at sacral buildings). Moreover, the extraction sites were assessed by using geomorphosite concept. For the evaluation, a method proposed by Reynard et al. (2016) was used. This method (including its modified versions) has been verified in several studies and

successfully used on different types of sites, including the geocultural ones (Boukhchim et al. 2018; Kubalíková et al. 2019, 2020). To every criterion, a value from 0 to 1 is attributed. The site that acquires ten and more points is considered relevant for geotourism development, respectively suitable for in-situ geotourist and geoeducational activities.

Based on this, specific geotourist and geoeducational activities are proposed: (1) educational and tourist activities in-situ, based on the fieldwork, literature review, historical, architectonical, archaeological research, and site assessment (guided walks, thematic geotrail, educational programme), (2) educational and tourist activities ex-situ (preparation of didactic materials, supporting information leaflets or various forms of on-line presentation that can be used both for education and "tourist" activities in the time of social distancing (e.g. StoryMaps, web pages, specific map layers that may be added to the GIS of Municipal Office of the Brno City, presented on the web pages of Tourist Information Centre of Brno or distributed to the local schools).

Study Area

Brno city lies on the contact of two large geological units: Bohemian Massif and Western Carpathians. This implies high lithological and morphological diversity and reflects a very complicated geological history.

The basement is formed by Neoproterozoic rocks of Brunovistulicum (metabasalts, granodiorites), which represent the oldest units within the study area (Hanžl et al. 2019). The Palaeozoic cover is represented especially by Devonian Basal Clastic (conglomerates and sandstones) and limestones. Also, the sedimentary rocks of Carboniferous and Permian age occur. Mesozoic cover in the study area consists of Jurassic limestones. The youngest material deposited in the area is represented by Neogene sands and gravels especially of marine origin and Quaternary loess and fluvial sediments (Müller and Novák 2000).

The geological sketch of the area is presented in Fig. 1, where the main deposits of building stone, namely, Crinoidea Limestone and Old Red Conglomerate and Sandstone is marked.

Results: an Integrative Approach to Building Stone as a Basis for Geotourism and Geoeducation

Old Red Conglomerate and Sandstone

Brief Characteristics

The thick, siliciclastic unit that typically mantles the Neoproterozoic crystalline rocks of Brunovistulicum has been described as the "Devonian Basal Clastics " or Moravian "Old Red " in the Czech geological literature (Nehyba et al. 2001). Similar sedimentary rocks ("Old Red Sandstone") occur in different parts of Europe, such as in Great Britain (Kendall 2017), Ireland (Fairey et al. 2018) or Norway, respectively Svalbard (Piepjohn and Dallmann 2014).

These reddish to purple coarse-grained clastics are interpreted as the deposits of an alluvial fan built up mainly by catastrophic sheetfloods. The provenance of the deposits was heterogeneous and geologically varied: main sources were probably granites and gneisses, other components were derived from rhyolites, older siliciclastic sediments, and low-grade metamorphic rocks (Buriánek et al. 2013; Nehyba et al. 2001). Material probably came from peneplenized terrain from which it was subsequently transported over a longer distance or previously deposited sediment was resedimented. Estimated thickness probably exceeds 100 m (Buriánek et al. 2013). Nehyba et al. (2001) describes the paleoenvironmental aspects of the genesis of basal clastics and identifies five facies on a model area of Červený kopec: (1) Facies A: pebbly conglomerate rhythmically interstratified with planar beds of parallel laminated pebbly sandstone (most distinctive and frequent, prevailing), (2) Facies B: medium to coarse-grained gravely sandstone with cross or planar stratification (very limited extent), (3) Facies C: clast-supported conglomerates, ungraded, massive to crudely parallel bedded (very limited extent), (4) Facies D: medium to coarse-grained, granular or pebbly sandstone with coarser clasts concentrated near the base of the bed (limited extent), (5) Facies E: red mudstone or very fine sandstone, massive or parallel laminated (extremely rare, occurs as interbeds within previous facies). From the architectonical point of view, Facies A can be considered the most important (Mrázek 1993). The reddish to purple colour of the rock is caused by the presence of iron oxides and hydroxides in the matrix and indicate warm and dry climate in the time of formation (Nehyba et al. 2001).

Deposits

Two main deposits of the Old Red were identified in the study area and both are described in the Database of geological localities of the Czech Geological Survey (Czech Geological Survey 2020). Červený kopec (Fig. 2a) is partly protected as an Important Landscape Element according to Act n. 114/1992 Coll. (one exposure situated on the private land) and Žlutý kopec (Fig. 2b) is entirely protected in the same category. Both sites have the character of abandoned quarry with a limited occurrence of natural outcrops, however, it is not possible to clearly state which is natural and which has been modified by human activity.

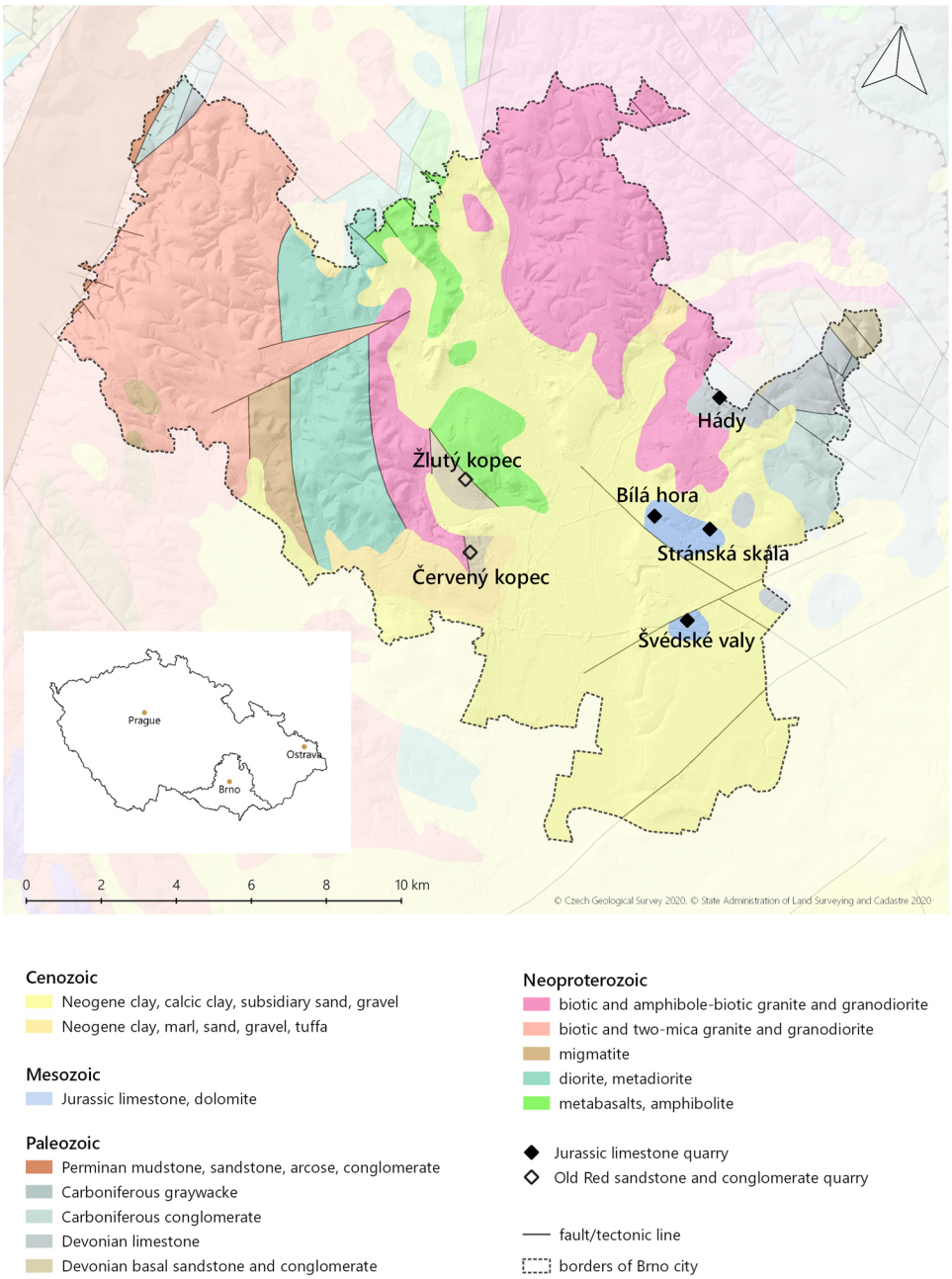

Fig. 1 Geological scheme of Brno city including the sites of extraction of Crinoidea Limestone and Old Red Conglomerate and Sandstone (source map: Czech Geological Survey 2020)

History of Extraction and Use

Old Red Conglomerate and Sandstone (Fig. 2c) were extracted already in prehistoric times. In the Early Middle Ages (eleventh century), the extraction became important as a resource for sacral buildings (Mrázek 1993). The extent and exact position of the quarry on Žlutý kopec in the Middle Ages is questionable, but at the map of Stable Cadastre (19th Century), the quarry is already registered. Quarrying reached its greatest extent in the second half of the nineteenth century. Both materials were also extracted on the northern slope of Červený kopec (Kamenná čtvrť – "Stone District"). The quarrying is also already registered on the maps of the Stable Cadastre and the deposit was extracted until the beginning of 20th Century (Kuča 2000). To a limited extent, the extraction continued in adjacent quarries until 1942 (Polák 1956).

In prehistory and the early Middle Ages, Old Red Conglomerate and Sandstone were used mainly for the reinforcement of furnaces and hearths (Mrázek 1993). During Romanesque epoch, the sacral buildings started to be constructed from local building stone. Old Red was used at two

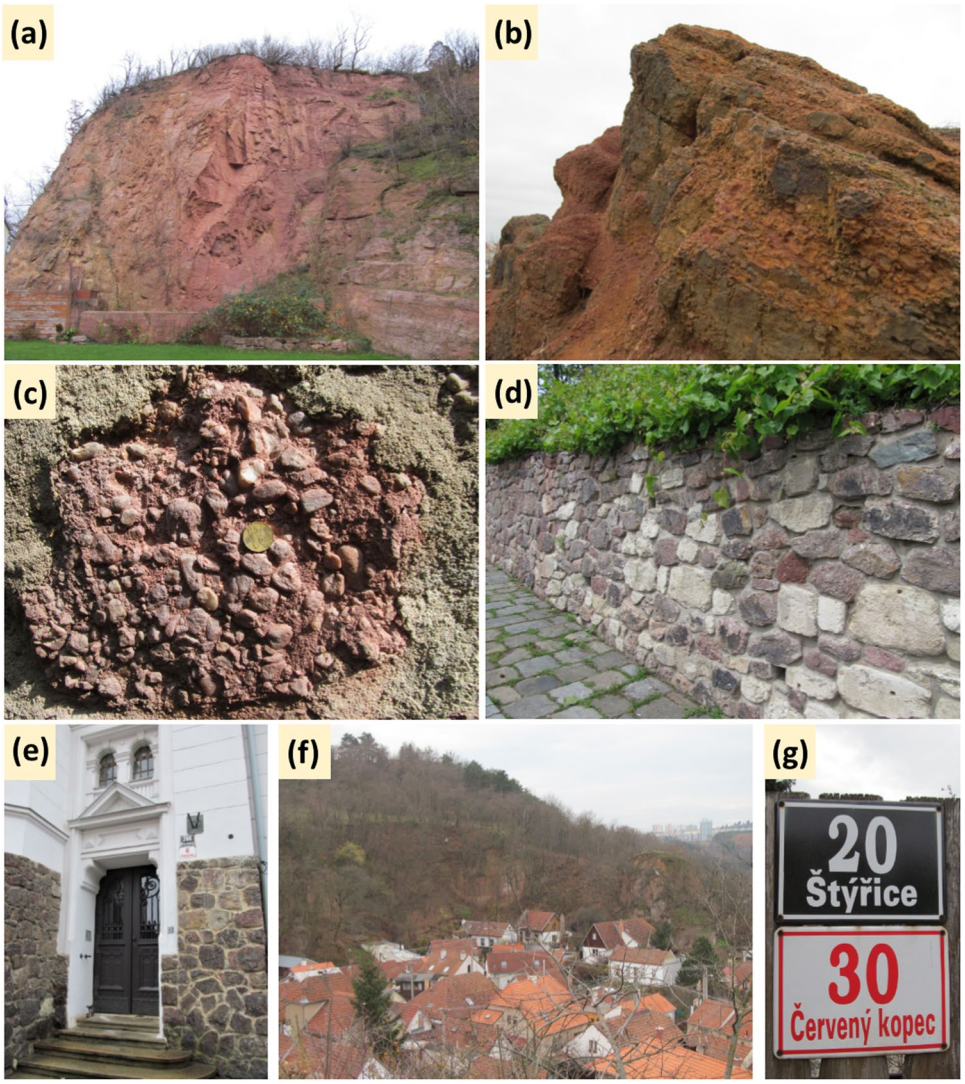

Fig. 2 **a** Červený kopec extraction site, **b** Žlutý kopec—outcrop protected as Important Landscape Element, **c** detail of Old Red Conglomerate (corresponding to Facies A), **d** use of Old Red Conglomerate and Sandstone on the terrace walls of Denisovy sady Park, **e** use of conglomerate at common municipal buildings at Biskupská Street, **f** a view on the worker's colony Kamenka, protected as cultural monument, **g** reflection of the colour of the rocks in toponyms: Červený kopec means Red Hill. All photos by authors.

oldest documented sacral buildings of the Brno City: rotunda from the 11th Century in the courtyard of the Old Brno Monastery (still existing, but inaccessible for public) and basis of the rotunda on Vídeňská Street which did not survive up to 13th Century (Merta and Sedláčková 2013; Zapletalová 2017). Other sacral buildings, on which the mentioned rocks were fully utilised, are the oldest phase of the church of St. Peter, especially its oldest crypt (Unger and Procházka 1995; Dvořák 1997) and Church of St. Giles in Brno-Komárov (Dvořák 1997).

The Old Red was also used on several extinct churches (usually, only basis were preserved and often destroyed by construction activity, however, rescue archaeological research was undertaken): Old Brno Church of St. Prokop; first mention 1243, extinct 1785 (Zapletalová and Peška 2005), Church of All Saints at Lochenberg; first mention 1260, extinct 1645 or Chapel of St. Nicholas built probably at the end of 13th Century, demolished in 1870 (Merta et al. 2000). During the first half of the 13th Century, Old Red started to be used for secular buildings: it can be found at Old Town Hall, eastern part of Špilberk Castle, city walls (Mrázek 1993; Dvořák 1997; Kolařík 2007) or Mintmaster's Cellar, in fact, the cellar of the house of the Old Brno Cistercians, probably from the first half of the 14th Century (Holub et al. 2003). Old Red was also used for the masonry of common houses up to beginnings of the 20th Century (Procházka 2000; Zapletalová and Peška 2005). Currently, the material is well visible at terrace walls of the park in Denisovy sady from the 19th and 20th Century (Fig. 2d), in the Streets Husova and Pellicova or at the houses on the Biskupská Street (Fig. 2e). These examples illustrate the importance of Old Red Conglomerate and Sandstone for the architectonical development of Brno City and take part at its typical appearance.

Other Cultural Aspects

Emergency Worker's Colony Kamenka in the Old Red Quarry of Červený Kopec On the bottom of the abandoned quarry on the northern slope of Červený kopec, an emergency colony started to be built on the turn of 19th and 20th Century. Emergency colonies in Brno were usually built on the places which were not suitable for other purposes (either industry or agriculture). This was a result of the economic crisis as many people could not pay rents in the rental houses. Small houses without any urbanistic plan (chaotic urban development) were constructed by employees of Kohn's brickworks that was situated on the southern slope of Červený kopec (Kuča 2000). As the bottom of the quarry is not directly the rock surface, but there is up to 15 m thick layer of weathered material, waste and other artificial deposits and the area was influenced by quarrying for a long time, the stability is questionable (slope instabilities, rock fall) (Krejčí 2019).

The worker's colony Kamenka (also Kamenná čtvrť which means "Stone District") is the largest workers' colony in Brno, which at the same time has best preserved its character of emergency housing and a special urban arrangement (Fig. 2f). Thanks to this, it is protected as Cultural Monument (Národní památkový ústav—National Heritage Institute 2020). Currently, it represents an original place with a very strong genius loci and has become a favourite destination both for local people and tourists.

Toponyms The character of building stone, respectively the geological and geomorphological conditions of the sites where the Old Red was extracted, is reflected in toponyms (Fig. 2g): Červený kopec means Red Hill and it refers to the colour of the conglomerate and sandstone. In this area, there are numerous street names that refer to geodiversity (red rocks or rocky terrain): Kamenná Čtvrť (Stone District), Pod Červenou Skálou (Under the Red Rock), Kamenná (Stony Street). The toponym of Žlutý kopec (Yellow Hill) is rather confusing. The elevation is also being built by Old Red conglomerate, but on the eastern slopes, thick layers of loess were deposited during Quaternary and quarried since Middle Ages—that is the reason why the Hill is called "Yellow".

Poetry Žlutý kopec as a distinctive elevation with specific natural conditions and rich history inspired several artists to include this extraordinary site in their poems. Petr Bezruč (1867–1958), a Silesian poet who lived for a long time in Brno, wrote the poem "Stužkonoska modrá" (The Blue Underwing) and Ivan Blatný (1919–1990), a native of Brno and a member of Skupina 42 (group of poets who significantly influenced Czech post-war poetry) mentioned Žlutý kopec in his collection Melancholické procházky (Melancholic walks) (Brno Poetic 2020).

Crinoidea Limestone

Brief Characteristics

Jurassic carbonate sediments in the study area are relics of the large carbonate platform covering the east of Moravia. This platform probably communicated with the Jurassic platform in northern Bohemia through the sea strait. Significant facial variability of carbonates in the territory of Brno points to its morphological diversity. Brno's Jurassic carbonate rocks were deposited in the shallow water environment where the biogenic, oolitic, and pelmikrit limestones prevail. To a lower extent, coral reefs are also developed (Tomanová Petrová 2014). The limestone is paleontologically important, according to Gregorová (2001), the first paleontological findings were discovered during the 19th Century. In practise, all significant groups of Jurassic (Oxfordian) marine fauna are included, e.g. crinoids, cephalopods or decapods (Gregorová 2001; Müller and Novák 2000; Hyžný et al. 2015).

Jurassic carbonate rocks were traditionally divided into four types (Czech Geological Survey 2020, Tomanová Petrová et al. 2014): (1) Fine-grained micrit, biomicrit, and pelmicrit limestone, (2) Coarse-grained stony breccia limestone that was deposited in the margins of carbonate plateau (approximately 30 m), (3) Crinoidea Limestone (approximately 4 m thick) deposited in a shallow-water environment, (4) Fine-grained micrit limestone with biogenic material (12 m thick). All these limestone types contain flints. Different facies of Jurassic limestone can be found on Hády quarry, where it represents the material deposited in the shelf lagoon environment. From the architectonical point of view, Crinoidea Limestone can be considered the most important (Mrázek 1993).

Deposits

The sedimentary rocks of Jurassic age have been preserved at several outcrops especially on the southeastern part of the city, namely, Stránská skála, Bílá hora, Hády, and Švédské valy (the last one does not exist anymore). Generally, Jurassic limestone is buried under the Neogene and Quaternary sediments (Czech Geological Survey 2020; Tomanová Petrová et al. 2013; Buriánek et al. 2013).

The denudation relic of Jurassic limestone at Stránská skála (Fig. 3a) was significantly transformed by human activity (quarrying, digging underground tunnels) and currently it is difficult to say which landforms are of natural origin (sinkholes) and anthropogenic origin. According to Mrázek (1993), small quarries date back to the Middle Ages. Thanks to its high morphological diversity (denudation relic, significant outcrops, quarries, exposed rock surface, karst features—both superficial and underground), and specific

Fig. 3 (**a**) Jurassic limestone outcrop at Stránská skála extraction site, **b** detail of the Crinoidea Limestone, **c** use of Crinoidea Limestone on Parnas Fountain on Zelný Trh Square, **d** use of Crinoidea Limestone at Old Town Hall portal, **e** decorations of the entrance gates are stored in municipal museum, **f** one of the demolished city gateways built of Crinoidea Limestone—Jewish Gate. Photos by authors (**a, b, c, d**), pictures taken from Mrázek 1993 (**e, f**).

lithological conditions, the site offers numerous ecosystem services (Kubalíková 2020). The quarrying stopped in 1925 and temporarily renewed during 1940–1944 (Polák 1956). Currently, the site is protected as National Natural Monument according to the Act n. 114/1992 Coll. (Agency for the Nature Conservation of the Czech Republic 2020).

Bílá hora (in older literature Nová hora—Polák 1956), another denudation relic, is situated west of Stránská skála. On the southern slope, numerous outcrops of dolomitized limestone can be found. The abandoned quarry on the foothill is paleontologically and stratigraphically important and was extracted until 1930, but currently, the access is limited as it is situated on the private land (Czech Geological Survey 2020; Buriánek et al. 2013).

The exposure on the Hády quarry represents a denudation relic which was deposited directly on the Devonian limestones and was extracted together with them. It is well observable from the lower bench of the Hády quarry and the border between Devonian and Jurassic limestones is visible even from more distant parts of Brno city (Tomanová Petrová et al. 2013).

A specific deposit of Jurassic limestone was extracted on Švédské valy, significant paleontological locality (Müller and Novák 2000). According to Polák (1956) the quarrying dates back to Middle Age and quarry was still in operation in the 1950s, but then, the deposit was quickly mined and currently, on the surface, there is no remnant of any limestone outcrop.

History of Extraction and Use

The extraction of flints at Stránská skála is confirmed by archaeological findings from about 45,000 years ago—flints were used for mature chipped industry (Bartík et al. 2019; Škrdla and Plch 1993). The exploitation of Crinoidea Limestone (Fig. 3b) is younger and dates back probably to the end of the 12th Century (Zapletalová 2020). This was proved by a relationship with built heritage—two churches within Brno city where the Crinoidea Limestone was used (St. Kunhuta in Zábrdovice and St. Giles in Komárov). Based on the detailed historical-architectonical research, it was confirmed the provenance of building material at these churches. Crinoidea Limestone from Stránská skála or Švédské valy was used for the St. Giles Church in the second phase of its architectonic development (Dvořák 1997). The character of the material corresponds to the material extracted in the early years after opening the quarry—it is partly affected by weathering and has a light yellow colour (in opposite, the raw Crinoidea Limestone is rather white). St. Kunhuta Church (the date of the consecration of the church 1211, beginning of the construction is possible already in 1201–1202) also possesses some Crinoidea Limestone features. Knowledge of architectonical use of Crinoidea Limestone contributed to the knowledge of historical and architectonical development of these churches (Zapletalová 2020).

Consequently, the research on the use of Crinoidea Limestone also helps to the clarification of the date of the opening of the quarries at Stránská skála or Švédské valy. Traditionally, it was supposed to be on the beginning of the thirteenth century (Mrázek 1993), however, thanks to the architectonical and historical research, it can be assumed that the quarries could be opened already on the turn of the twelfth and thirteenth century or at the end of the 12th Century (Zapletalová 2020).

Concerning the use of Crinoidea Limestone, shortly after opening the quarries at Stránská skála and Švédské valy, it became an important building stone for Brno Mediaeval architecture (Mrázek 1993; Dvořák 1997). Thanks to its qualities (hardness, resistance to climatic conditions, and easy processing), it became favourite and used for numerous buildings (both sacral and secular) including the decoration features. The most distinctive are Parnas Fountain on Zelný trh Square (Fig. 3c), Old Town Hall's portal (Fig. 3d), Zderad's Column, and decoration of the entrance gates to the city—today, they do not exist with an exception of Měnínská Gate; the decorations from the demolished gates (Fig. 3e, 3f) are stored in the municipal museum (Mrázek 1993). Crinoidea Limestone was used both as building stone (walls of St. Peter and Paul's Cathedral, terraces of Denisovy sady Park, and Špilberk Castle) and decoration stone (see examples above). Other examples (e.g. architectonical elements on various portals, window and door lining, decoration in the Špilberk castle—sedilias, vaulting, and fine sculpture) were presented by Mrázek (1993). Selected cultural functions (both linked to the extraction sites and use of material) were presented and discussed by Kubalíková et al. (2019) or Kubalíková (2020).

Based on the above mentioned, it can be stated that Crinoidea Limestone can be treated as a heritage stone for Brno and its surroundings. For this, further research should be carried out and in the future, there is a possibility of considering the application of Heritage stones (IUGS 2020).

Other Cultural Aspects

A Contribution to the Scientific Knowledge Deposits of Jurassic limestone are important paleontological localities where numerous species have been described. Stránská skála has become the typical site for Moravian palaeontology, both Jurassic and Quaternary (Gregorová 2001; Musil, 1995; Boriová et al., 2019). Also, there is a contribution to the paleogeographical research, however, this is linked especially to the geomorphological aspects of Stránská skála and Bílá hora and not directly to the building stone (Kubalíková 2020).

Archaeological research on Stránská skála brought many new insights and knowledge with regard to Palaeolithic settlements (Valoch 1995; Svoboda and Bar-Yosef 2003), including the evidence of the first use of fire in centroeuropean area (Přichystal and Strnad 1995).

Anthropogenic Landforms—Links to Industrial Heritage Thanks to the existence of underground karst features at Stránská skála, this extraction site was temporarily used for industry. During World War II, it was decided that the factory Flugmotorenwerke Ostmark would be moved to the underground. Several hundred metres of tunnels were dug and partly, natural cavities were used (Mrázek 1993). Later, they were used as bombshelters and civil defence objects.

Toponyms Bílá hora means White Mountain (in fact, it is not mountain, but hill) which refers to the white colour of limestone.

Poetry Stránská skála inspired the poet Karel Blažek (born 1948). His poem "Ze Stránské skály" (From Stránská skála) refers to the ancient settlements and hunters who lived at this extraction site 45, 000 years ago (Brno poetic 2020).

Assessment of Extraction Sites

There are six important sites where the Crinoidea Limestone and Old Red Conglomerate and Sandstone were extracted (Fig. 1). The assessment of the sites is presented in Table 1.

Four extraction sites reached the score of 10 points and higher, thus, they can be considered suitable for the development of geotourist and geoeducational activities in-situ. Červený kopec and Žlutý kopec generally acquired high scientific values and added values. Other criteria were assessed as average, however, in the case of Červený kopec, the safety and threats obtained a lower score, so this has to be taken into account when planning the activities.

Concerning the assessment of extraction sites of Crinoidea Limestone, only two sites acquired score higher than ten points. Both Hády and Stránská skála have high scientific and added values, the educational values also reached a high score. Tourist infrastructure on both sites is comparable. According to the assessment, the extraction sites Bílá hora and Švédské šance cannot be considered suitable sites for geotourist and geoeducational activities in-situ. Bílá hora has lower scientific and added values and moreover, its educational values are rather average. Švédské šance is a specific site, not suitable for in-situ activities as the Earth-science phenomena are not existing there. However, it can be used as a reference site for ex-situ activities to accompany the information about the history of mining and palaeontological research.

Geotourist and Geoeducational Activities Based on the Integrated Approach to Natural and Cultural Aspects of Building Stones

The research on building stones in Brno city has numerous aspects and generally, it can be divided in two main directions: extraction sites and use of material itself. Consequently, the research is linked to the different aspects as can be seen in Fig. 4. The research on sites of extraction contributes to the Earth-science knowledge (including geological mapping), sites themselves are important as wildlife habitats. Abandoned quarries often form an inseparable part of city's panorama, they may be an inspiration for arts and can represent a part of natural heritage (or geoheritage). Research on the use of material contributes to the historical knowledge, the material used as building or decorative stone forms identity and cocreates the typical appearance of a city, architectonical features, and sculptures where the material is used can represent a part of cultural heritage. Both sites of extraction and use of the material can be treated as an important aspect of local mining and industrial history and agents that influenced urban development. Likewise, both entities can serve as an important resource for (geo)tourism and (geo)education or environmental education which encompasses geography, biology, and history with possible overlaps to other subjects and domains. Integrative approach to the heritage protection and conservation comes out the fact that both sites of extraction and architectonical features where the material is used may be a part of heritage (both natural and cultural).

Specific monuments and buildings where these two distinctive building stones were used are included in the Brno Centre Geotrail (available at https://ticbrno.cz/sites/default/files/download/ticbrno-neziva-priroda-en-web.pdf), namely, the stop 1—St. Peter and Paul Cathedral (diversity of building stone), stop n. 5—Pellicova Street (use of local material), and partly stop 7—Gazebo on Špilberk (panoramic view on Brno including several extraction sites, geomorphological settings). The detail of the terrace wall in Denisovy sady Park, which was used as a cover photo for geotrail leaflet

Table 1 Assessment of extraction sites in the study area

Values/Site		Červený kopec	Žlutý kopec	Hády	Stránská skála	Bílá hora	Švédské šance
Scientific value	Integrity and current status	0.75	1.00	1.00	1.00	0.75	0.00
	Rarity	0.75	0.50	1.00	0.75	0.50	0.50
	Representativeness	1.00	1.00	1.00	1.00	0.50	0.00
	Paleogeographical significance	0.75	0.50	1.00	1.00	0.50	0.50
Added value	Ecological value	0.00	0.50	1.00	1.00	0.50	0.00
	Cultural value	1.00	0.25	0.25	0.50	0.25	0.75
	Aesthetic value	1.00	0.75	0.75	1.00	0.50	0.00
Tourist value	Accessibility	0.75	1.00	0.50	1.00	0.75	0.75
	Safety	0.25	1.00	0.50	0.75	0.75	0.75
	Tourist infrastructure and facilities	0.75	0.75	0.75	0.75	0.50	0.00
	Visibility	0.75	1.00	1.00	1.00	0.50	0.00
Conservation value	Legislative protection	0.50	0.50	1.00	1.00	0.75	0.00
	Current threats	0.50	0.75	0.50	0.75	0.50	0.00
Educational value	Interpretive facilities	0.50	0.50	1.00	1.00	0.25	0.00
	Educational interest	0.75	0.75	1.00	1.00	0.50	0.25
Total geotourist value		**10.00**	**10.75**	**12.25**	**13.50**	**8.00**	**3.50**

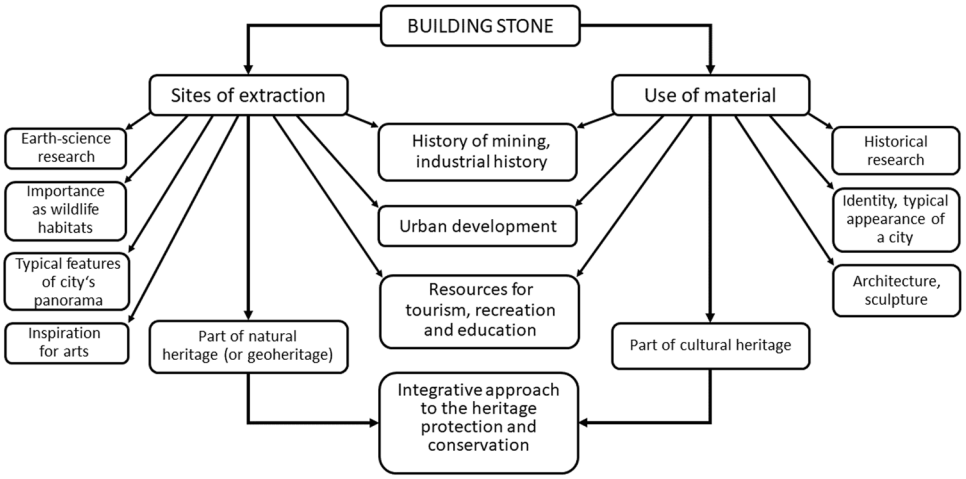

Fig. 4 Selected aspects of building stone research (source: own processing)

reflects the diversity of the building stone of Brno (Fig. 5). The colours of two iconic materials for Brno's Mediaeval architecture—red conglomerate or sandstone and white Crinoidea Limestone match with colours of the city. The extraction sites of Hády, Stránská skála, Červený kopec, and Žlutý kopec are also presented on the web pages of the Tourist Information Centre as tourist attractions of the city (Tourist Information Centre of Brno 2020). Several extraction sites (Stránská skála, Hády, Žlutý kopec) are presented in a leaflet "700 million years beneath our feet", which has been prepared together with Brno Municipal Office and which promotes geoheritage of the city. Currently, the leaflet is available in Czech, German and English.

The topic of building stone and related aspects are implemented in didactic materials "Geodiversity in Brno city" which are focused on the links between geodiversity, natural and cultural heritage and are suitable for the students between 13 and 18 years (two last stages at secondary schools and high school). These materials represent a core of a 2-h educational programme which includes both ex-situ activities (presentation, exhibition of rock samples) and in-situ activities on suitable extraction sites and buildings where the Crinoidea Limestone and Old Red Conglomerate and Sandstone were used.

Concerning the activities which could be available even during the times of social distancing, further work is focused on the creation of a StoryMap which would tell a story not only of Crinoidea Limestone and Old Red Conglomerate and Sandstone, but it would also include the Devonian limestone from Hády (including coral "marble" which is used on the Obelisque at Denisovy sady Park), metabasalts extracted at Petrov and Špilberk, Neogene sands and gravels extracted at the southern part of the city or Quaternary loess (important relationship to the built heritage, extinct brickyards which are reflected in toponyms etc.).

In the future, based on the research and complex assessment of extraction sites, on-site activities and facilities are going to be processed including preparation of guided excursions for public or leaflets about the iconic building materials. This is going to be prepared in cooperation with organisations which take care of legally protected sites in the study

Fig. 5 The front page of Brno Centre Geotrail leaflet (available at https://ticbrno.cz/sites/default/files/download/ticbrno-neziva-priroda-en-web.pdf). The colours of the building stones (Crinoidea Limestone and Old Red Conglomerate and Sandstone) on the terrace wall of Denisovy sady Park match with the colours of the city (red and white)

area (namely, Agency for Nature Conservation of the Czech Republic and Brno Municipal Office) and Tourist Information Centre which promotes tourist attractions in the city.

These activities can serve as complementary for traditional school learning (according to the curricula in subjects such as geography, biology, history, or ecology) and support a multidisciplinary approach in learning and project teaching. As these activities partly take place outside, the importance of outdoor learning can be also emphasised.

Conclusions

This case study proved that natural and cultural heritage are closely linked and that research on building stone as well as an integrative view on the heritage concept can bring new insights and perspectives into the interpretation of natural and cultural heritage in a given area. In the case of Brno city, the integrative view and multidisciplinary research on building stone (1) contributed to the historical knowledge and clarification of the historical dating, (2) enabled to see the building stone as an intersect of cultural and natural heritage (respectively geoheritage) which encompasses different aspects (architecture, industrial heritage, toponyms, geological and geomorphological settings, and literature), (3) together with extraction sites assessment, it served as a basis for geotourist and geoeducational activities. The multidisciplinary approach to the topic of building stone has immense importance for further research directions, promotion, environmental education, and other activities that can contribute to the holistic view on this important resource and can help to accept the conservation measures, related both to natural and cultural heritage.

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Declarations

Conflict of interest The authors declare no conflict of interest.

References

Act No. 114/1992 Coll. Available at https://www.zakonyprolidi.cz/cs/1992-114. Accessed 28th August 2020.

Arouca Declaration (2011) International Congress of Geotourism – Arouca 2011, Associação Geoparque Arouca. Available at http://www.europeangeoparks.org/?p=223. Accessed 30th November 2018

Agency for the Nature Conservation of the Czech Republic (2020) The list of protected areas and sites. Available at https://drusop.nature.cz/portal/. Accessed 28th August 2020

Baucon A, Piazza M, Cabella R, Bonci MC, Capponi L, Neto de Carvalho C, Briguglio A (2020) Buildings that 'Speak': Ichnological Geoheritage in 1930s Buildings in Piazza della Vittoria (Genova, Italy). Geoheritage 12:70. https://doi.org/10.1007/s12371-020-00496-x

Bartík J, Škrdla P, Šebela L, Přichystal A, Nejman L (2019) Mining and processing of the Stránská skála-type chert during the Late Neolithic and Early Eneolithic periods. Archeologické rozhledy 71:373–417

Bennett MR, Doyle P, Larwood JG, Prosser CD (eds) (1996) Geology on Your Doorstep: the role of urban geology in earth heritage conservation. The Geological Society, London

Bonomo AE, Acito AM, Prosser G, Rizzo G, Munnecke A, Koch R, Bentivenga M (2019) Matera's old quarries: geological and historical archives that need protection and valorization. Geoheritage 11:1603–1619. https://doi.org/10.1007/s12371-019-00413-x

Boriová S, Sázelová S, Novák M, Štelcl J, Svoboda J (2019) Human and non-human taphonomic efects on faunal remains from the Late Upper Paleolithic: a case study from the Stránská skála IV site. Czech Republic Int J Osteoarchaeol 30(2):155–169

Boukhchim N, Fraj TB, Reynard E (2018) Lateral and "Vertico-Lateral" Cave Dwellings in Haddej and Guermessa: characteristic Geocultural Heritage of Southeast Tunisia. Geoheritage 10(4):575–590

Brno Poetic (2020) Brno Poetic… or connecting poetry with geography. https://www.brnopoeticke.cz/index.php?lang=en. Accessed 26th August 2020

Brocx M, Semeniuk V (2019) Building stones can be of geoheritage significance. Geoheritage 11:133–149. https://doi.org/10.1007/s12371-017-0274-8

Buriánek D, Bubík M, Franců J, Fürychová P, Havlíček P, Havlín A, Gilíková H, Janderková J, Kašperáková D, Kociánová L, Konečný F, Krejčí O, Krumlová H, Kryštofová E, Müller P, Otava J, Paleček M, Pecina V, Pecka T, Sedláček J, Šrámek J, Tomanová Petrová P, Večeřa J, Verner K, Vít J (2013) Vysvětlivky k základní geologické mapě České republiky 1:25 000, list 24–342 Brno-jih, Czech Geological Survey, 250 p.

Coratza P, Gauci R, Schembri J, Soldati M, Tonelli C (2016) Bridging natural and cultural values of sites with outstanding scenery: evidence from gozo, maltese islands, Maltese Islands. Geoheritage 8:91–103

Corbí H, Martínez-Martínez J, Martin-Rojas I (2019) Linking geological and architectural heritage in a singular geosite: Nueva Tabarca Island (SE Spain). Geoheritage 11:703–716. https://doi.org/10.1007/s12371-018-0327-7

Czech Geological Survey (2020) Significant geological localities of the Czech Republic. http://lokality.geology.cz. Accessed 26th August 2020

da Silva CM (2019) Geodiversity and sense of place: local identity geological elements in portuguese municipal heraldry. Geoheritage 11:949–960. https://doi.org/10.1007/s12371-018-00344-z

De Wever P, Baudin F, Pereira D, Cornée A, Egoroff G, Page K (2017) The Importance of Geosites and Heritage Stones in Cities—a Review. Geoheritage 9(4):561–575

Del Lama EA (2019) Potential for urban geotourism: churches and cemeteries. Geoheritage 11(3):717–728

Dingwall (2005) Geological world heritage: a global framework. A Contribution to the Global Theme Study of World Heritage Natural Sites. IUCN, WCPA, UNESCO

Dowling RK, Newsome D (eds) (2018) Handbook of Geotourism. Edward Elgar Publishing, Cheltenham

Dvořák J (1997) Stavební kámen starší středověké architektury v Brně. In Z pravěku do středověku. Brno, pp 165–174

Fairey BJ, Kerrison A, Meere PA, Mulchrone KF, Hofmann M, Gärtner A, Sonntag BL, Linnemann U, Kuiper KF, Ennis M, Mark C, Cogné N, Chew D (2018) The provenance of the Devonian

Old Red Sandstone of the Dingle Peninsula, SW Ireland; the earliest record of Laurentian and peri-Gondwanan sediment mixing in Ireland. J Geol Soc 175:411–424. https://doi.org/10.1144/jgs2017-099

Gajek G, Zgłobicki W, Kołodyńska-Gawrysiak R (2019) Geoeducational Value of Quarries Located Within the Małopolska Vistula River Gap (E Poland). Geoheritage 11:1335–2135. https://doi.org/10.1007/s12371-019-00395-w

Goemaere E, Demarque S, Dreesen R, Declecq P (2016) The geological and cultural heritage of the caledonian stavelot-venn massif, Belgium. Geoheritage 8:211–233

Gordon JE (2018) Geoheritage, Geotourism and the Cultural Landscape: Enhancing the Visitor Experience and Promoting Geoconservation. Geosciences 8(4):136. https://doi.org/10.3390/geosciences8040136

Gregorová R (2001) Zkameněliny na Stránské skále. Stránská skála: Výjimečná lokalita. Brno, Czech Republic, Moravské zemské museum, pp 6–8

Hanžl P, Janoušek V, Soejono I, Buriánek D, Svojtka M, Hrdličková K, Erban V, Pin C (2019) The rise of the Brunovistulicum: age, geological, petrological and geochemical character of the Neoproterozoic magmatic rocks of the Central Basic Belt of the Brno Massif. Int J Earth Sci (geol Rundsch) 108:1165–2119. https://doi.org/10.1007/s00531-019-01700-2

Holub P, Merta D, Peška M, Zůbek A (2003) Poznámky k historické topografii Dominikánského náměstí. Brno v minulosti a dnes 17:41–77

Hyžný M, Starzyk N, Robins CM, Kočová Veselská M (2015) Taxonomy and palaeoecology of a decapod-crustacean assemblage from the Oxfordian of Stránská skála (Southern Moravia, Czech Republic). Bull Geosci 90:633–650

ICOMOS (1964) The Venice Charter for the Conservation and Restoration of Monuments and Sites. Available at https://www.icomos.org/charters/venice_e.pdf. Accessed 25th August 2020.

ICOMOS (1999) International cultural tourism charter. Managing tourism at places of heritage significance. Available at https://www.icomos.org/charters/tourism_e.pdf. Accessed 25th August 2020.

ICOMOS (2002) International cultural tourism charter. Principles And Guidelines For Managing Tourism At Places Of Cultural And Heritage Significance. International Council on Monuments and Sites, ICOMOS International Cultural Tourism Committee, 2002, 48 p.

IUGS (2020) Heritage Stones. Available at https://globalheritagestone.com/. Accessed 25th August 2020

Kendall RS (2017) The old red sandstone of Britain and Ireland—a review. Proc Geol Assoc 128:409–421

Kolařík V (2007) Opevnění města Brna do konce třicetileté války na základě archeologických výzkumů. MS Ústav archeologie a muzeologie FF MU, Brno

Krejčí O (2019) Historické těžby s aktuálními terénními projevy v rámci města Brna. MS Czech Geological Survey, Brno

Kubalíková L (2020) Cultural Ecosystem Services of Geodiversity: A Case Study from Stránská skála (Brno, Czech Republic). Land 9:105

Kubalíková L, Kirchner K, Kuda F, Machar I (2019) The Role of Anthropogenic Landforms in Sustainable Landscape Management. Sustainability 11(16):4331. https://doi.org/10.3390/su11164331

Kubalíková L, Kirchner K, Kuda F, Bajer A (2020) Assessment of urban geotourism resources: an example of two geocultural sites in Brno. Czech Republic. Geoheritage 12:7. https://doi.org/10.1007/s12371-020-00434-x

Kuča K (2000) Brno—vývoj města, předměstí a připojených vesnic. Baset, Brno

Larwood J, France S, Mahon C eds. (2017) Culturally Natural or Naturally Cultural? Exploring the relationship between nature and culture through World Heritage. United Kingdom: IUCN National Committee UK. Available at https://iucnuk.files.wordpress.com/2017/05/naturally-cultural-web.pdf. Accessed 9th February 2021

Liccardo A, Mantesso-Neto V, Piekarz GF (2012) Urban geotourism—education and culture. Anuário Do Instituto De Geociências 35:133–141

Marengo A, Borghi A, Bittarello E, Costa E (2019) Touristic fruition of the disused quarry of busca onyx: problematics and strategies. Geoheritage 11:47–54. https://doi.org/10.1007/s12371-018-0311-2

Martini G, Alcalá L, Brilha J, Iantria L, Sá AA, Tourtellot J (2012) Reflections about the geotourism concept. In: Sá AA, Rocha D, Paz A, Correia V (eds) Proceedings of the 11 European Geoparks Conference. Associação Geoparque Arouca, Arouca, pp 187–188

Merta D, Sedláčková L (2013) Druhá Starobrněnská Rotunda. Vlastivědný věstník moravský 56:14–34

Merta D, Peška M, Sadílek J, Urbánková K (2000) Kostel sv. Mikuláše na Dolním trhu v Brně. Brno v minulosti a dnes 13:107–132

Mrázek I (1993) Kamenná tvář Brna. Moravské zemské muzeum, Brno, 238 p.

Müller P, Novák Z (2000) Geologie Brna a okolí. Český geologický ústav, Praha

Musil R ed. (1995) Stránská skála Hill. Excavation of Open-Air Sediments 1964–1972; Moravské zemské muzeum: Brno, Czech Republic, 213 p

Národní památkový ústav - National Heritage Institute (2020) Catalogue of cultural monuments. http://www.pamatkovykatalog.cz/. Accessed 30th August 2020

Nehyba S, Leichmann J, Kalvoda J (2001) Depositional environment of the "Old Red" sediments in the Brno area (south–eastern part of the Rhenohercynian Zone, Bohemian Massif). Geol Carpathica 4(52):195–203

Palacio-Prieto JL (2015) Geoheritage within Cities: urban Geosites in Mexico City. Geoheritage 7(4):365–373

Pereira D, Van den Eynde VC (2019) Heritage Stones and Geoheritage. Geoheritage 11:1–2. https://doi.org/10.1007/s12371-019-00350-9

Pica A, Reynard E, Grangier L, Kaiser C, Ghiraldi L, Perotti L, Del Monte M (2018) GeoGuides, Urban Geotourism Offer Powered by Mobile Application Technology. Geoheritage 10(2):311–326

Piepjohn K (2014) Dallmann WK (2014) Stratigraphy of the uppermost Old Red Sandstone of Svalbard (Mimerdalen Subgroup). Polar Res 33:19998. https://doi.org/10.3402/polar.v33.19998

Polák A (1956) Soupis lomů ČSR, číslo 50, List Brno (4357). Prague, Czech Republic, Nakladatelství Československé akademie věd, 63 p

Polck MAdR, de Medeiros MAM, de Araújo-Júnior HI (2020) Geodiversity in Urban Cultural Spaces of Rio de Janeiro City: Revealing the Geoscientific Knowledge with Emphasis on the Fossil Content. Geoheritage 12:47. https://doi.org/10.1007/s12371-020-00470-7

Přichystal A, Strnad M (1995) The evidence of fire use by the hominids of the species Homo erectus at the Stránská Skála Hill in Brno. In Stránská skála Hill. Excavation of Open-Air Sediments 1964–1972. Moravské zemské Muzeum, Brno, Czech Republic, pp 149–152

Procházka R (2000) Zrod středověkého města na příkladu Brna. In Mediaevalia archaeologica 2. Brno a jeho region. Praha – Brno, 7–158

Prosser CD (2019) Communities, Quarries and Geoheritage—Making the Connections. Geoheritage 11:1277–1289. https://doi.org/10.1007/s12371-019-00355-4

Reynard E, Giusti C (2018) The Landscape and the Cultural Value of Geoheritage. In: Reynard E, Brilha J (eds) Geoheritage: Assessment, Protection, and Management. Elsevier, Protection and Management, pp 147–166

Reynard E, Perret A, Bussard J, Grangier L, Martin S (2016) Integrated approach for the inventory and management of geomorphological heritage at the regional scale. Geoheritage 8(1):43–60

Reynard E, Pica A, Coratza P (2017) Urban geomorphological heritage. An Overview. Quaest Geographicae 36(3):7–20

Robinson EA (1982) Geological walk around the City of London—royal exchange to Aldgate. Proc Geol Assoc 93:225–246

Scarlett JP, Riede F (2019) The dark geocultural heritage of volcanoes: combining cultural and geoheritage perspectives for mutual benefit. Geoheritage 11:1705–1721. https://doi.org/10.1007/s12371-019-00381-2

Škrdla P, Plch M (1993) Osídlení epigravettienu v okolí Stránské skály (okr. Brno-město). Archeologické rozhledy 45:429–435

Svoboda J, Bar-Yosef O (2003) Stránská Skála. Origins of the upper paleolithic in the Brno Basin, Moravia, Czech Republic. Peabody Museum of Archaeology and Ethnology, Harvard University: Cambridge, MA, USA, Volume D

Tomanová Petrová P, Baldík V, Bubík M, Buriánek D, Franců J, Fürychová P, Gilíková H, Havlín A, Janderková J, Kociánová L, Kolejka V, Krejčí O, Krejčí V, Kryštofová E, Kunceová E, Otava J, Paleček M, Pecina V, Pecka T, Rez J, Sedláček J, Sedláčková I, Skácelová Z, Švábenická L, Večeřa J, Vít J (2013) Vysvětlivky k základní geologické mapě České republiky 1:25 000, list 24–431 Šlapanice. Czech Geological Survey, 219 p

Tourist Information Centre of Brno (2020) GO TO BRNO'S CENTRE GEOTRAIL. Available at https://www.gotobrno.cz/en/explore-brno/go-to-brnos-centre-geotrail/. Accessed 27th August 2020.

UNESCO (1972) Convention concerning the protection of the world cultural and natural heritage. Retrieved from: http://whc.unesco.org/archive/convention-en.pdf. Accessed 22nd October 2018

UNESCO (2017) Operational Guidelines for the Implementation of the World Heritage Convention. Available at https://whc.unesco.org/en/guidelines/. Accessed 30th December 2018

Unger J, Procházka R (1995) Počátky katedrály sv. Petra a Pavla v Brně ve světle archeologických výzkumů 1991–1992. Brno v minulosti a dnes 13:90–111

Valoch K (1995) Early Human activities at the Stránská skála Hill. In Stránská skála Hill. Excavation of Open-Air Sediments 1964–1972. Moravské zemské muzeum: Brno, Czech Republic, pp 159–168

Zapletalová D (2017) Stav poznání raně středověkého hradu Brna. Brno v minulosti a dnes 30:11–56

Zapletalová D (2020) Dva brněnské románské emporovékostely a jejich vztah k další brněnské zděné architektuře. Co prozrazuje krinoidový vápenec? Brno v minulosti a dnes 33:11–42

Zapletalová D, Peška M (2005) Nové poznatky ke starobrněnskému kostelu sv. Prokopa a jeho okolí. Brno v minulosti a dnes 18:529–555