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Urban geotourism development and geoconservation: Is it possible to find a balance?

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ABSTRACT

Geodiversity is a basis for geotourism development. Geosites and geodiversity sites then represent particular issues of geotourist interest, however, in some cases, their potential and suitability for the geotourism is not recognized. The paper is focused on the geotourism potential assessment that forms a basis for sustainable use of geodiversity in an urban area. By using the set of criteria for assessing geosites and geomorphosites, the mutual relationships between particular values are examined and based on the assessment and statistical methods, the classification of the sites regarding their suitability for geotourism development is elaborated. The results show that the suitability of the sites for geotourism does not always depend on the degree of legal protection, but rather on the educational values or scientific values of geosites and geodiversity sites. Based on the classification, the conceptual development of geotourist activities can be proposed.

1. Introduction

Geodiversity is defined as "the natural range (diversity) of geological (rocks, minerals, fossils), geomorphological (landforms, topography, physical processes), soil and hydrological features. It includes their assemblages, structures, systems and contribution to landscapes" (Gray, 2013). This concept presents the geodiversity as value-free quality of the natural environment and although it has been discussed and eventually contradicted (Brocx and Semeniuk, 2019), it is generally accepted by wide scientific community (Brilha et al., 2018; Schrodt et al., 2019; Gray and Gordon, 2020).

The key role of geodiversity was already recognized especially thanks to its essential importance to biodiversity (Hjort et al., 2015; Bailey et al., 2018; Tukiainen et al., 2019) and thanks to numerous functions and services that offers to human society (Gray, 2013). These services and functions can be divided into several groups according to the abiotic ecosystem services approach (Gordon and Barron, 2012; Gray, 2018a; Reverte et al., 2020; Fox et al., 2020): regulating, supporting, provisioning and cultural services.

The cultural values and services of geodiversity span from the historical aspects, influence on cultural diversity and religious importance (Gordon, 2018), mythological aspects (Piccardi and Masse, 2007), artistic or symbolic importance (da Silva, 2019) to the tourist and recreational importance (Hose, 2012; Dowling and Newsome, 2018; Gray, 2018b). Moreover, knowledge functions (Gray, 2013; Kubalíková, 2020) can also contribute to the cultural value of geodiversity as these may become a resource for educational activities related to the development of sustainable forms of tourism. Indeed, geodiversity is a basis for geotourism, a form of sustainable tourism that focuses on landscape and geology, but also on the biotic and cultural features that are linked to the abiotic nature (Dowling, 2013; Dowling and Newsome, 2018). In the last decades, the geotourism has experienced a considerable growth all over the world and currently, it is being accepted as an equivalent concept to the other types of sustainable tourism (Hose, 2012; Dowling and Newsome, 2018; Ólafsdóttir, 2019).

The exploitation of geodiversity for tourist purposes is usually done by exploitation of particular sites. These sites can be viewed as geosites (sensu stricto (Brilha, 2016); also geoheritage sites which are important from the scientific point of view) or geodiversity sites (which do not have to be a part of geoheritage). The geosites are defined as portions of

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the geosphere that present a particular importance for the comprehension of Earth history, geological or geomorphological objects that have acquired a scientific, cultural/historical, aesthetic and/or social/-economic value due to human perception or exploitation (Reynard, 2004). As there exist specifities of geomorphological heritage (Coratza and Hobléa, 2018), a term geomorphosite is sometimes used: geomorphosites are defined as the landforms to which a value can be attributed and they can be used by society as a geomorphological resource (Panizza, 2001). In specific cases, the term geocultural site is introduced and it is defined as a site where geological features interact with cultural elements (Boukhchim et al., 2018; Reynard and Giusti, 2018).

For the purposes of geotourism, it is suitable to use the term "geodiversity sites" or "sites of geotourist interest" because both geosites sensu stricto and other types of the sites can be considered.

Both geosites and geodiversity sites deserve a certain degree of protection and suitable management as they represents issues that should be conserved for the future generation (Brilha, 2016) or they represent an important educational or tourist resource, eventually the sites with important cultural or historical aspects (Reynard and Giusti, 2018).

The relationship between geotourism and conservation efforts were already discussed (Pereira et al., 2009; Crofts and Gordon, 2015; Dowling and Newsome, 2018; Gray, 2018a; Wolf et al., 2019; Williams et al., 2020) and usually, this relationship is considered mutually beneficial. Nevertheless, in specific cases it is difficult to find a compromise, especially in urban areas (Palacio-Prieto, 2015; Kubalíková et al., 2017, 2020; Reynard et al., 2017; Erikstad et al., 2018). Geodiversity in towns and cities plays a crucial role and has been studied from various points of view (Habibi et al., 2018; Thornbush and Allen, 2018), but it is also exposed to higher tourist and recreational pressure or endangered by urban development (Kubalikova et al., 2019; Lama et al., 2015). In these terms, the protection is desirable as it is one of the tool of how to conserve the valuable sites before the inappropriate urban development or the overexploitation of the sites for recreational purposes.

In the Czech Republic, the legislative protection of natural sites is anchored in Act 114/1992 Coll., numerous sites are protected as Nature Reserves or Nature Monuments or declared as Important Landscape Elements - ILE (Agency for Nature Conservation, 2020). Also, the Czech Geological Survey (state institution under the Ministry of Environment) possesses solid database of geodiversity sites (Czech Geological Survey, 2020). Some of the sites are already exploited for geotourism purposes, but some of them (despite its potential) are not. In specific cases, the exploitation for (geo)tourist and recreational purposes is not in accordance with conservation strategies, there are some conflict between geotourism and geoconservation similar to those identified by Williams et al. (2020). Thus, redesigning of management measures is desirable.

In this paper, the geotourist potential of various types of geodiversity sites in an urban area (case study: Brno City, Czech Republic) is assessed based on the evaluation of their scientific, educational, added, tourist and conservation value. The second aim of the paper is to explore the relationships between particular values and characteristics of these geodiversity sites and the relationships between the degree of protection and its suitability for geotourism development (or geotourist potential). Third goal of the paper is to make a classification of the geodiversity sites in relation to their geotourist potential. Based on this, specific management proposals can be designed to balance protection (geoconservation measures) and geotourism development.

2. Methods

The first step of the assessment was the identification of geodiversity sites in the study area. This was based on the detailed literature review and field work. Following types of sites were considered:

1) Legally protected sites
   a with higher degree of protection according to the Act 114/1992 Coll. (category National Nature Monument, National Nature Reserve)
   b with lower degree of protection according to the Act 114/1992 Coll. (category Nature Monument, Nature Reserve)
   c with basic degree of protection (category Important Landscape Element) – based on the fieldwork, all the geological ILE and several biological and hydrological ILE with remarkable geodiversity aspects were selected
2) Sites not legally protected, but included in the Database of Geological Localities kept by Czech Geological Survey (CGS) which are being monitored; some of the sites are proposed to be protected legally (Czech Geological Survey, 2020)
3) Sites with no legal protection and not included in the Database of Geological Localities

Numerous methods for geosite and geomorphosite assessment have been introduced and critically reviewed (Brilha, 2016; Reynard et al., 2016; Štrba et al., 2018; Mucivuna et al., 2019). For the assessment of the sites of geotourist interest, a set of criteria based on methods presented by Pereira et al. (2009), Brilha (2016) and Reynard et al. (2016) was applied (Table 1). To every criterion, a value from 0 to 1 was attributed, no weights were used for the assessment. A specific value (scientific, educational, added, tourist, conservation) of the site was made as simple average of partial criteria.

The total geotourist potential was calculated as a simple average of all the values. Based on this, a simple ranking and classification was done.

Statistical analysis was based on the values acquired for every site. The five main synthetic indicators (scientific, educational, added, tourist and conservation values) were correlated with each other to reveal the relationships between them. Because the Kolmogorov-Smirnov test showed that some indicators did not have a normal distribution, a nonparametric Spearman's ρ was used (Spearman, 1904). This analysis was applied in order to recognize the possible relationships between particular values.

Then, cluster analysis was performed by the k-means clustering method (Lloyd, 1982). Five main synthetic indicators were used as input data; analysis was performed for 2–5 clusters. Based on the number of iterations needed to achieve the result and the results of ANOVA, a solution was chosen. This analysis contributed to the classification of the geodiversity sites from the geotourism development point of view. This procedure is repeatable and enables to analyse and sort the geodiversity sites in various areas of interest. Based on that, specific proposals balancing the conservation needs and geotourism development can be designed for every group of the sites.

2.1. Study area

Brno is the second largest city in the Czech Republic (population approximately 380 000 inhabitants) situated in the south-eastern part of the country (Fig. 1). Its position on the contact of the two geological units – Bohemian Massif and Carpathian Foredeep implies high lithological and morphological diversity.

The Brno Massif (part of Brunovistulicum, eastern Bohemian Massif) which form the basement is the Cadomian magmatic body (570–600 Ma) composed of the Eastern and Western Granodiorite Area. These two zones are separated by the Metabazite Zone composed of metamorphosed basalts with geochemistry similar to basalts of mid-ocean ridges (Finger et al., 2000). These metabasalts are the oldest part (730 Ma) of the Brno Massif (Hanžl et al., 2019).

The Paleozoic cover is represented by basal clastic sediments (conglomerates and sandstones) and limestones. In a few isolated cases in the southeastern part of the study area, the Mesozoic (Jurassic) limestones occur. The Neogene sediments of the Carpathian Foredeep cover the Brno Massif preferentially along the tectonically predisposed valleys.

Table 1
Criteria used for the assessment of geotourist potential of sites.

Values	Criteria	scoring
Scientific value (SV)	Integrity and current status of the geodiversity site	0 – bad conditions, site damaged; 0.25 – bad conditions, with a possiblitity to recover; 0.5 – average; 0.75 – good; 1 – excellent conditions
	Rarity (uniqueness)	0 – the phenomenon on site is not rare; 0.5 – several similar sites; 1 – the unique site in the study area
	Inner diversity of the Earth-science features (phenomena)	0 – just one phenomenon; 0.25 – two different phenomena; 0.5 – 3 phenomena; 0.75 – 4 phenomena; 1 –5 and more phenomena at a site
	Scientific knowledge	0 – site is practically unknown for the geo-scientific community; 0.5 – locally known; papers in national journals; 1 – scientific papers about the site in the international journals
	Paleogeographical significance	0 – no or very limited importance (e.g. for geological mapping); 0.5 – partial importance for Earth sciences research; 1 – site has palaeogeograpghical value or it is considered key locality
Educational value (EV)	Representativeness	0 – site is not representative; difficult to see the phenomena; 0.5 – site partially representative with a help of interpretative materials; 1 – typical occurence of phenomena, high representativeness
	Didactic and interpretative potential	0 – practically not possible to understand and recognize the phenomena; 0.25 – possible to understand, but with explanations from professionals; suitable for students or informed public; 0.5 – possible to understand with explication from professional guide; 0.75 – possible to understand just with leaflet or information pannel; 1 – easy to understand and recognize the phenomena
	Existing interpretative materials	0 – no materials; 0.25 – geodiversity aspects mentioned, but primary, the promotion materials focus on different aspect (e.g. cultural); 0.5 – existing materials about the geodiversity aspects on the web; 0.75 – leaflets, supporting material ex-situ; 1 – geodiversity of the site is well promoted in-situ (informative panels, educational path)
Added value (AV)	Ecological aspect	0 – geodiversity has no important relation to the ecological aspects, no occurence of ecological aspects on the site; 0.5 – occurence of protected species or other ecological phenomena; 1 – geodiversity supports the occurence of protected species or specific ecosystems
	Aesthetic aspect	0 – not interesting (hidden); 0.25 – partly interesting (e.g. interesting colours or structure of geodiversity features); 0.5 – interesting (colour contrasts, interesting structure); 0.75 – aestheticaly valuable (interesting setting in surrounding landscape, colour contrasts); 1 – fascinating (big contrasts, impressive setting in the surrounding landscape)
	Cultural aspects (e.g., historical, archeological, architectonic, artistic)	0 – no cultural aspect; 0.25 –1 cultural aspect; 0.5 –2 different cultural aspects; 0.75 –3 different cultural aspects; 1 –4 and more different cultural aspects
Tourist value (TV)	Visibility	0 – no or very limited (with special equipment); 0.25 – limited; 0.5 – observable from one viewpoint and well visible; 0.75 – geodiversity features are observable from two different viewpoints and well visible; 1 – very good visibility, 3 and more viewpoints
	Accessibility	0 – more than 1 km both from a parking place and stop of public transport; 0.25 – less than 1 km from parking place, but more than 1 km from the stop of public transport; 0.5 – the stop of public transport and/or parking place in the distance 0.5 and 1 km; 0.75 – the stop of public transport and/or parking place less than 0.5 km; 1 – the stop of public transport and/or parking place parking place no more than 200 m from the geosite
	Safety	0 – proven or ongloing danger phenomena (rockfall, landslides) that may endanger visitors, access at own risk; 0.25 – existing, but limited danger phenomena that can endanger visitors; 0.5 – hypothetical danger phenomena, but if the safety rules are respected, the site is quite safe for the visitors; 0.75 – site is quite safe; 1 – site is safe for everyone, the movement on the site cannot be dangerous
	Tourist infrastructure and facilities	0 – no facilities; 0.25 – very limited (paths, not marked); 0.5 – tourist paths leading to the site (or close to it); 0.75 – marked tourist paths, tourist shelters, benches; 1 – complete infrastructure (paths, shelters, eventually some stalls with drinks and food or local products)
Conservation value (CV)	Current threats (vulnerability)	0 – existing and ongoing processes that lead to the destruction of the site with no plans to recover it; 0.25 – the site currently endangered by anthropogenic activities, but there are plans how to decrease this impact; 0.5 – potential threats that can endanger site, but they are managed or they are possible to decrease if they occur; 0.75 – low anthropic risks, existing natural threats that are well managed; 1 – site is not endangered by natural processes or human activities
	Legislative protection	

(continued on next page)

Table 1 (*continued*)

Values	Criteria	scoring
		0 – without legal protection, not in the Database of geosites of the Czech Geological Survey; 0.25 – included in the Database, ongoing monitoring of the site, but no legal protection; 0.5 – category Important Landscape Element; 0.75 – category Natural Monument/Reservation; 1 – category National Natural Monument/Reservation

Calcareous clays with sands and gravels at the base are often covered by Quaternary loess and fluvial deposits (Müller and Novák, 2000).

The study area belongs to the two different geomorphological provinces: Bohemian Highlands and Western Carpathians which implicates a variety of landforms (Demek et al., 2015). In the northern and central parts, the relief is tectonically influenced (occurrence of horsts, grabens and tectonically conditioned valleys of Svratka and Svitava Rivers) and more pronounced. Numerous small water courses have cut into the rocks of Brno Massif or Paleozoic cover and created the dense network of small, but relatively deep valleys separated by ridges. They are usually well preserved and have a high ecological and landscape values which make them attractive for local people and tourists (Buček and Kirchner, 2011). The southern part is rather flat due to the occurrence of less resistant Neogene and Quaternary sediments. Typical landforms are represented by alluvial plains and fluvial landforms (e.g., remains of meandering water courses, oxbow lakes).

The study area is strongly influenced by the anthropogenic activity (the occurrence of numerous urban/residential, communication, industrial, mining and other anthropogenic landforms). The exploitation of construction material (building stone, sand, gravel, loess) can be traced back to the 12th century (Mrázek, 1993). Today, a considerable number of abandoned quarries and pits is legally protected.

Based on the literature review and detailed field work, 89 geodiversity sites were identified in different geological and geomorphological settings (Fig. 2). They include 3 National Nature Monuments/Reserves, 27 Nature Monuments/Reserves, 26 Important Landscape Elements, 19 sites included in the Database of CGS and 14 sites with no legal protection.

3. Results and discussion

3.1. Site assessment and classification of the sites

In total, 89 sites were evaluated by using the method for geosite assessment. An overview of the values acquired is presented in Table 2.

In the case of scientific value, a relatively higher percentage (cca 37 %) of the sites are rated below average, which is caused by lower rarity (there are only few extraordinary sites in the study area) and lower paleogeographical importance and scientific knowledge (numerous sites known only at local/national level and not recognized internationally).

Concerning educational value, over 40 % of the sites reached the above average score and only one fifth of all the sites acquired the score below average. Thus, the educational potential of the sites is high, which also indicates high potential for geotourism development as the educational aspect represents one of the pillars of sustainable geotourism (Dowling and Newsome, 2018). It should be noted that in the case of high educational potential, the Earth-scientific values do not need to reach high values (average are sufficient), but it is important that the features are visible and comprehensible for lay public (Różycka and Migoń, 2018; Gajek et al., 2019).

The distribution of the assessment of added value is similar to the scientific value. Lower scores are caused especially by the low average score for cultural value (0.34 for all the sites). Added value is

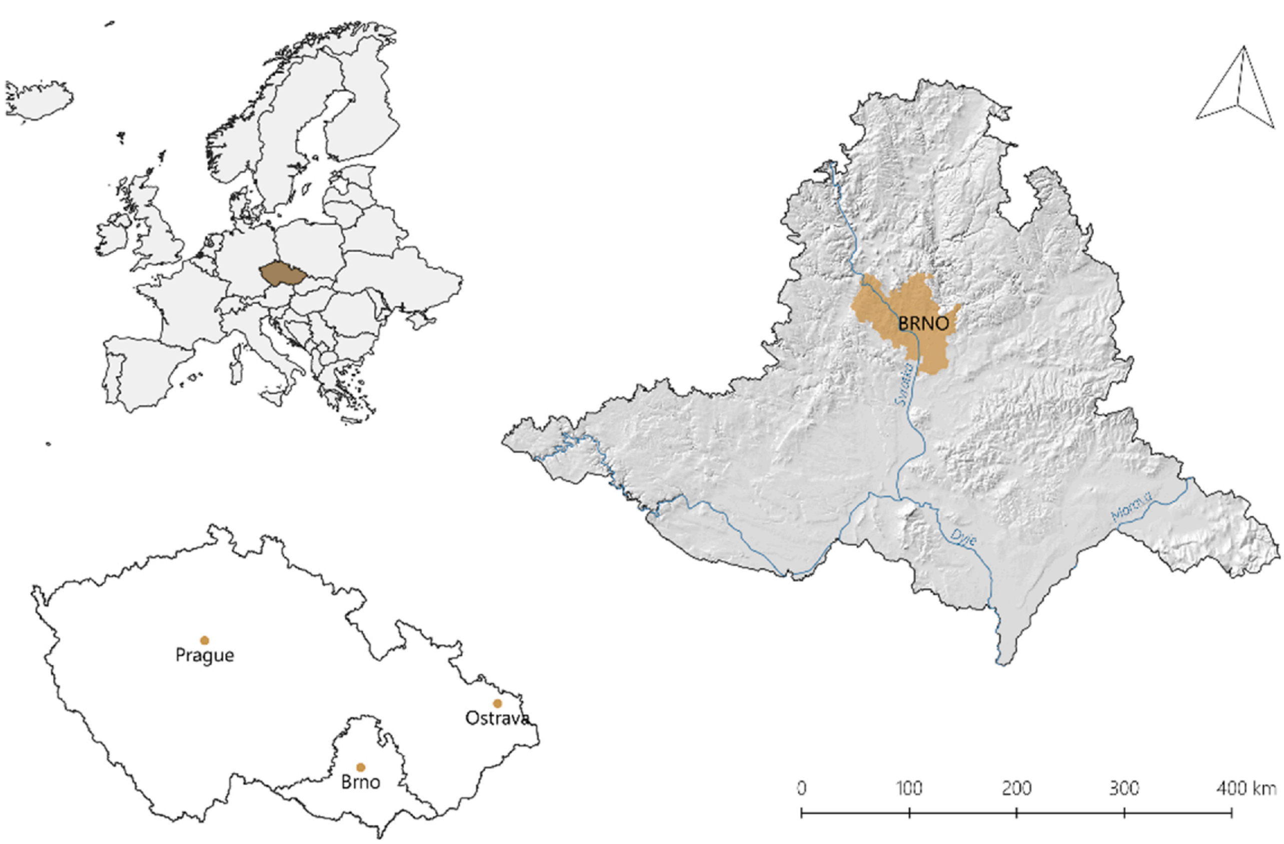

Fig. 1. Situation map of the study area.

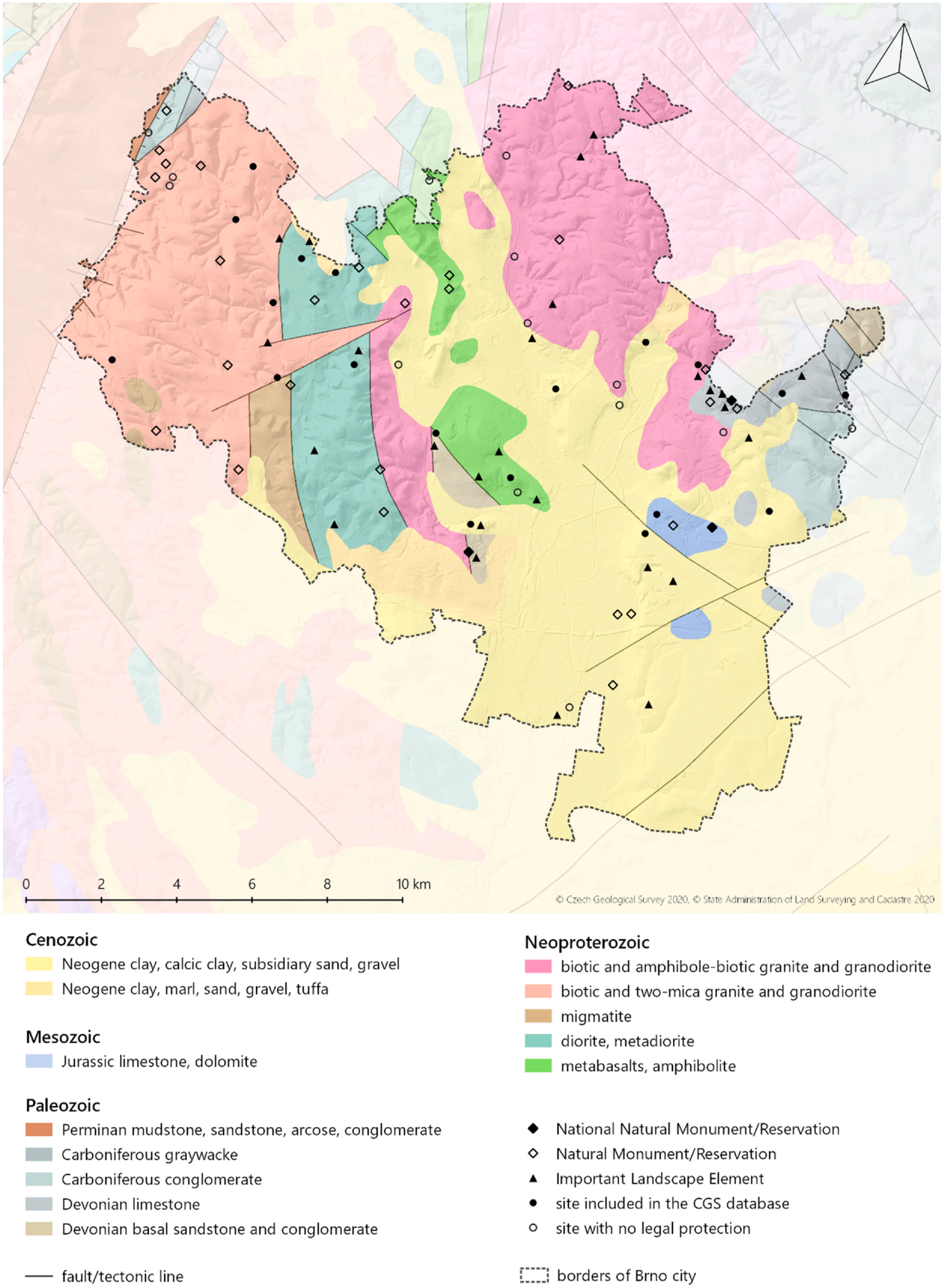

Fig. 2. Geological scheme of the study area with sites included into the assessment.

Table 2
An overview of the sites according to the values. The numbers show the percentage of the sites that acquired certain value.

	scientific value	educational value	added value	tourist value	conservation value	total geotourist value
% of the sites with low score (0.00−0.19)	13.48	6.74	16.85	0.00	3.37	0.00
% of the sites with the score below average (0.20−0.39)	23.60	14.61	22.47	17.98	37.08	19.10
% of the sites with average score (0.40−0.59)	38.20	35.96	40.45	35.96	42.70	51.69
% of the sites with the score above average (0.60−0.79)	14.61	20.22	15.73	35.96	13.48	25.84
% of the sites with high score (0.80−1.00)	10.11	22.47	4.49	10.11	3.37	3.37

significantly important for the geotourism development and geotourism activities as it enables to set the links between Earth-science aspects and the environment (living nature, history, culture) which is in accordance with contemporary approach to geotourism (Arouca Declaration, 2011; Dowling and Newsome, 2018). Nevertheless, lower or not existing added values are not an obstacle for geotourism development. In specific cases, the added value can be increased, e.g. by organisation of cultural events on sites or direct involvement of local communities (Worton and Gillard, 2013; Prosser, 2019; Stoffelen, 2020).

Over 45 % of the sites has acquired the above average or high score in tourist value. This is caused by position of the sites in the urban area where the accessibility is usually relatively high (numerous sites easily accessible by public transport) and existing tourist infrastructure (marked paths or shelters directly on the sites and accompanying services such as catering or accommodation situated in close proximity of the sites). Numerous sites within urban areas traditionally serve as recreational background for the locals or they are situated in or close to the public parks or greenery, so the presence of accompanying infrastructure is logical.

In the case of conservation values, majority of the sites (over 40 %) is rather vulnerable probably because of existing urban development pressure (some sites can be situated in the conflict areas or endangered by construction activities) or higher recreational and tourist pressure (some sites are frequently visited) which is accompanied by insufficient protection (Erikstad et al., 2018; Kubalikova et al., 2019).

Concerning total geotourist values, no sites fell into the lowest category and nearly one third of them reached above average or high scores. This may implicate that these sites are suitable for developing geotourist activities, however, various aspects such as geoconservation efforts or sustainable management of the sites have to be taken into account (Williams et al., 2020). Moreover, when designing practical geotourist activities or when developing (geo)tourist infrastructure on the sites (new educational paths, accompanying safety equipment, shelters), each site should be considered again individually.

3.2. The results of the correlation

The results of the statistical analysis are shown in Table 3 and Fig. 3. Some pairs show significant correlations. The highest values of ρ are reached by the scientific-added value and scientific-educational value pairs. The correlation between tourist and educational values can be also considered significant. On the contrary, no statistically significant correlation was found for the scientific-tourist value, scientific-conservation value and tourist-conservation value pairs.

Moreover, the correlation between the simple criteria conservation status and ecological values was performed. In this case, the results show significant correlation (0.5650***). When applying this procedure to the criterion conservation status and other criteria and values (total scientific value: 0.0979, integrity: 0.2017, inner diversity: 0.1470, rarity: 0.0157, paleogeographical importance: 0.0161, scientific knowledge: 0.0353, total added value: 0.3037**, cultural value: -0.1301, aesthetical value: -0.0159), no significant correlation was found.

The correlation between the criterion conservation status and total geotourist value was also performed – the Spearman's ρ is 0.3418***, so correllation can be considered as average.

Low correlation between Earth-scientific and conservation values may be caused by the fact that geodiversity sites have often lower protection than sites with biological aspects and may be more vulnerable and exposed to various threats. Very frequently, the importance of the Earth-science aspects is not recognized when identifying potential protected sites (be they important landscape elements of natural reserves/ monuments) and protected sites are rather declared based on their biological value (e.g. existence of threatened species). This may correspond with the high correlation between conservation status and ecological values.

This result may also indicate that the sites with ecological value are usually protected more often than sites just with Earth-scientific values. Also, in the past, the sites that were declared as protected, were usually proposed for protection by biologists as this direction in nature conservation has generally prevailed (Brilha, 2002; Gray, 2013; Schrodt et al., 2019).

Low correlation between Earth scientific values and tourist values can be caused by the fact that the geotourist potential of the sites has not been recognized yet and thus, the site is not used for geotourist purposes (Cocean and Cocean, 2016; Bouzekraoui et al., 2017). In some cases, the safety can be an important limiting factor as numerous sites with high Earth scientific values are abandoned quarries where the basic and adequate infrastructure (such as paths or information about the safety and limitations of the movement on the site) has not been established or there is only a warning that entry is at own risk or the site can be situated on private lands.

High correlation between scientific and added value may indicate that valuable Earth-scientific sites usually have high ecological values, e. g. rocky outcrops, valleys or abandoned quarries represent a refugee of protected species or the ecosystems of the quarries has often high biodiversity (Betard, 2013). This underpins the importance of geodiversity for biodiversity (Tukiainen et al., 2019), however, a more detailed study would be required in this field to prove this hypothesis (Bailey et al., 2018). Also, geodiversity sites with higher scientific values can have strong links to the cultural heritage or history (Coratza and

Table 3
Spearman's ρ for selected indicators.

	Scientific value	Educational value	Added value	Tourist value	Conservation value
Scientific value	xxx	0.5787***	0.5858***	0.1093	0.1598
Educational value	0.5787***	xxx	0.4637***	0.5183***	0.2945**
Added value	0.5858***	0.4637***	xxx	0.3005**	0.3862***
Tourist value	0.1093	0.5183***	0.3005**	xxx	0.1755
Conservation value	0.1598	0.2945**	0.3862***	0.1755	xxx

*** $p < 0.001$.
** $0.001 < p < 0.01$.

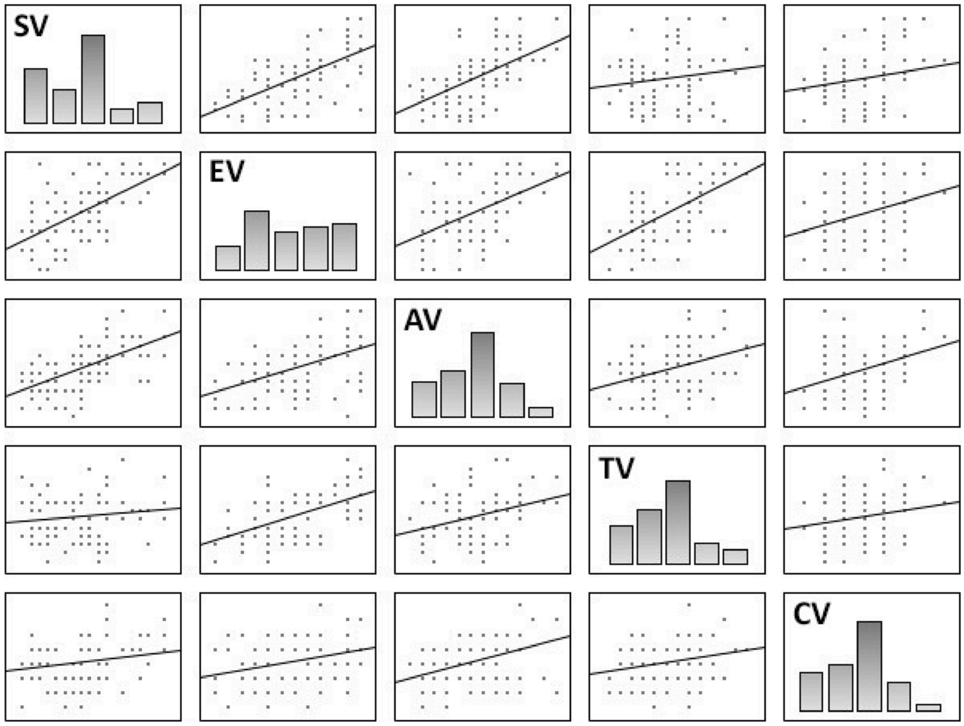

Fig. 3. Correlation matrix for selected indicators (SV – scientific value, EV – educational value, AV – added value, TV – tourist value, CV – conservation value).

Hobléa, 2018; Gordon, 2018; Reynard and Giusti, 2018). Very often, the abandoned quarries were the resource of material from which local buildings or monuments were constructed or they served as a basis for knowledge about the geology or paleogeography of the region (Gordon, 2018; Prosser, 2019; Kubalíková, 2020).

Educational value correlated well with all the other values (with exception of conservation value). The sites with higher scientific values are probably more suitable for educational activities (which should accompany the geotourist ones) especially thanks to the higher inner diversity, paleogeographical importance and scientific knowledge (Gajek et al., 2019). The significant relationship between educational and tourist values is caused probably by the fact, that sites that have already some tourist or recreational value, are often used as sites for educational purposes (excursions) or there is an accompanying educational infrastructure (educational path, information panel). These two values are logically closely linked.

3.3. *The results of k-means clustering*

Based on the cluster analysis (k-means clustering method), a solution that uses four clusters was chosen. Cluster 1 consists of 18 cases, cluster 2 of 27, cluster 3 of 19 and cluster 4 of 25 cases. The results of the cluster analysis shown in Fig. 4 indicates that there are interesting differences between the individual clusters. Clustering was proposed to do in order

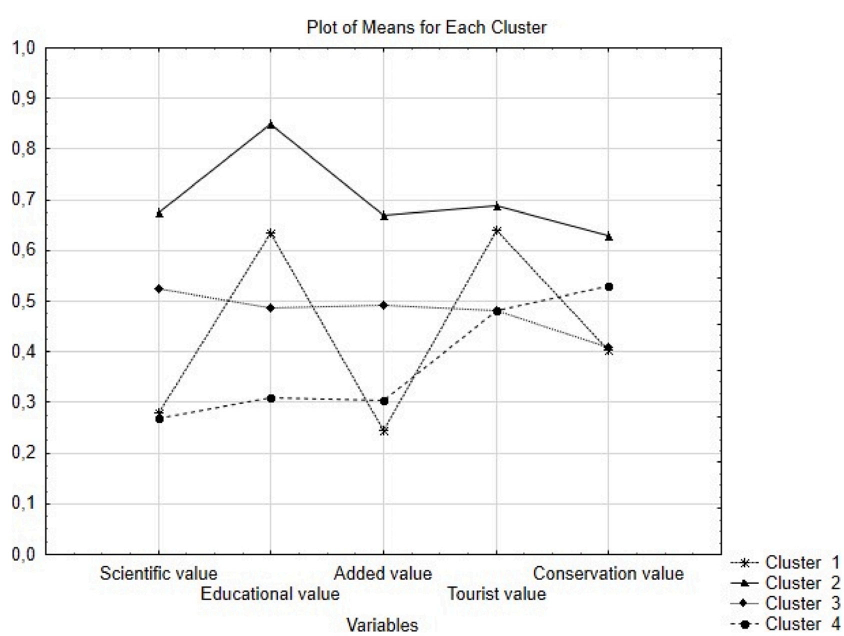

Fig. 4. Results of k-means clustering.

to recognize the types of sites according to their suitability for geotourism development.

The highest values for all indicators are reached by cluster 2, whose members can be described as "top sites". All the values are relatively high (including conservation value), thus these localities should form the backbone network of urban geotourism offer, as these are generally the most interesting sites. However, the further development of geotourist activities has to be in accordance with conservation principles (Brilha, 2016; Gray, 2018a; Williams et al., 2020). Although the conservation value is high (legal protection, lower degree of threats), it has to be remembered that the keeping of this current status is desirable and it is necessary to avoid the destruction of the site (Kubalikova et al., 2019). It is also possible that as a consequence of development of geotourist activities on the sites, the number of visitors will be growing as well as the pressure on the site. In this case, conduct rules co-created by the visitors can be a solution for these sites, eventually, the volunteering on the sites or other types of active involvement of potential visitors can contribute to the wide acceptation of conservation measures on the site. These activities help to emphasize the importance of the Earth-science value of the site and communities can thus play an important role in geoconservation efforts and sustainable management of these sites (Worton and Gillard, 2013; Pijet-Migoń and Migoń, 2019; Prosser, 2019).

From the point of view of geotourism, sites from cluster 1 could also be suitable, as they have a high educational and tourist value. Although their scientific and added value is relatively low, they can complement cluster 2. Such geosites can then be transformed into places of education and cognition, recreational facilities can be built in them, etc. As the conservation value of these sites is rather low (the sites are vulnerable and the protection is not sufficient), it is desirable to balance the conservation needs when developing tourism. It can be suitable to do educational and tourist activities with guide or a person who can emphasize the conservation aspect of the site and point on the risks and threats to the site.

The cluster 3 can be seen as average and concerning the geotourist development, it is comparable with cluster 1. Also, in this case, the conservation efforts has to be emphasized when using these sites for geotourism purposes (be they tourist, recreational, sport or education).

From a geotouristic point of view, the least suitable are the sites in cluster 4, which reaches below-average values for the first four indicators, but has a relatively high conservation value. These sites could be used e.g. for environmental education with focus on biology (on sites where there is an important ecological aspect) with emphasizing the links of biodiversity / geodiversity.

Based on this, a classification of the geodiversity sites can be proposed (Table 4).

As mentioned before, when considering the geotourist development on particular sites, the selected site has to be treated individually as the classification serve only like guidelines or inspiration for development of geotourist and geoeducational activities.

Table 4
Classification of geodiversity sites according to their potential for geotourism development.

group	Corresponds to the cluster n.	description	management	Examples
1	2	Sites with high values including the conservation value	"Backbone" or "top sites" of the geotourist offer. Development of geotourism is possible when respecting the conservation aspects.	Stránská skála (National Nat. Monument) Žlutý kopec (ILE) Písečník (not protected)
2	1	Sites with high educational and tourist value and average other values	These sites can complement the "top sites". The management of geotourist activities has to be in coherence with principles of sustainability and general nature protection.	Maloměřický lom (ILE) Obřany – brněnské písky (included in CGS Database) Jednovnická street cutting (not protected)
3	4	Sites with average values and higher conservation value	Sites that should stay aside the main geotourist activities. In specific cases can be seen as a complementary for first two groups and can be used for environmental education with focus on biology with emphasizing the links of biodiversity / geodiversity	Medlánecká skalka (Natural Monument) Holásecká pískovna (ILE) U Zetoru (included in CGS Database)
4	3	Sites with average values	In specific cases, they could be used for environmental education (nature conservation aspects) and complement the network of principal sites (from the groups 1 and 2)	Žebětínský rybník (Nat. Monument) Stará řeka (ILE) Ostroh hradu Veveří (not protected)

4. Conclusions

Both geosites and geodiversity sites can have a considerable potential for geotourist development. The degree of protection does not automatically mean that the site is suitable for the geotourism development. Rather, an educational value and some aspects of scientific values are a basis for further geotourist development. Added values can increase the potential too. Concerning tourist values, this can be increased by specific management measures (constructing accompanying tourist infrastructure, improving safety on the sites).

The results provided a new insight into the relationship between different values that can be acquired by geodiversity sites. Clustering allowed to classify the geodiversity sites in order to the possibility of geotourism development. Four groups of the sites were identified – the development of geotourist activities is possible and effective on three of them, the fourth cluster represents rather a basis for environmental education in general. However, when developing geotourist activities, it has to be remembered that tourist and recreational use has to be in balance with conservation needs.

The results of the research will serve as a basis for development of geotourist and educational activities on selected sites within the Brno city and can be implemented in planning documents and strategies of the city, if further steps are taken (e.g. extended SWOT analysis, reconsidering selected sites etc.). Generally, this methodological approach can be applied when there is a solid database of geodiversity sites as it provides possibility to establish priority sites for geotourism development in urban areas.

Authors' contribution

Lucie Kubalíková: Conceptualization; Data curation; Investigation; Formal analysis; Methodology; Resources; Writing; Supervision

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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