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Research article

Prevention of damage to sandstone rocks in protected areas of nature in northern Bohemia

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Abstract: One of the most interesting natural tourist destinations in the Czech Republic are sandstone rocks, located mainly in the Bohemian Cretaceous Basin. Sandstones in these areas create a number of aesthetically valuable geomorphological formations, such as rock towers, gates, windows, overhangs etc. In addition, they provide beautiful views. Regions with a concentration of sandstone rocks are thus among the most visited natural areas in the Czech Republic. Unfortunately, mass tourism also brings negative impacts that negatively affect the condition of sandstone rocks—these are mainly engraving in the rocks, painting or spraying on the rocks, vandalism, pollution by garbage or excrements and destruction of natural rock shapes. However, it is not true that a larger number of visitors automatically means a larger number of negative impacts. This paper analyses the factors that influence the occurrence of the above-mentioned negative impacts in areas of sandstone rocks. The basis for the analysis was mapping of negative impacts in the field, data on traffic to individual geosites, GIS database of business entities in the tourism sector in the area of interest and field survey, aimed at explaining the structure of visitors to individual geosites according to their motivation and preferences. First, data on tourists' motivation and preferences were processed using cluster analysis into their typology. Then, the relationship between the intensity of the occurrence of negative impacts and potential factors—the absolute number of visitors, the distance to a major tourist facility and the type of visitor—was analysed. The results showed that damage to geosites is most affected by some types of visitors and little social control.

Keywords: sustainable tourism; mass tourism; geoheritage; destination management; overtourism

1. Introduction

Protecting and preventing the destruction of the geoheritage is one of the basic pillars of geotourism [1]. Due to the importance of this topic, a number of authors deal with it in their scientific works. In a number of publications, you can find articles devoted to the quantification of damage to geosites [2], the reasons for the existence of this damage [3], various forms of anthropogenic pressure [4], or the specifics of certain types of geosites [5]. There are also many papers that deal with the practical implementation of the protection of geosites [6–9] and the prevention of negative impacts, through education [10,11] or geosite management [12,13]. Although all these approaches contribute to mitigating damage to the geoheritage, it is virtually impossible to prevent this negative trend completely.

With the continuous increase in the number of tourists in nature reserves in the Czech Republic, there is an increase in various damage to the geoheritage [14]. The sandstone rocks of the Bohemian Cretaceous Basin are among the most endangered, but they are also among the most valuable geosites in the Czech Republic [15]. The increase in the number of visitors to some of the most interesting geosites is huge: it has grown by up to 250–300% in the last 5 years (data is only available for geosites, where admission is paid; Kamenice river gorges are the most visited destination in the Bohemian Switzerland National Park: in 2018 it was visited by 402,000 visitors, while in 2013 by 136,200 only. A similar steep increase in traffic can be seen at Pravčická brána, which was visited by 270,800 tourists in 2018 and 107,700 in 2013. The only geosite with a paid entrance in the territory of the UNESCO Global Geopark Bohemian Paradise is Prachovské skály, the number of paying visitors was 162,500 in 2018 and 105,000 in 2013) [16]. Increasing anthropogenic pressure is then reflected in an increase in the number and intensity of negative impacts such as engraving in the rocks, painting or spraying on the rocks, vandalism, pollution by garbage or excrements and destruction of natural rock shapes. Although there is a relationship between the growing number of tourists and the growing damage to the rocks, it cannot be said that more visitors means more damage to the geosites. Some highly visited geosites are only slightly damaged, while some less visited are severely damaged. For some geosites, nature conservation authorities have even decided to ban visitors altogether due to extreme damage to the rocks [14,16].

If the number of visitors is not the only reason for rock damage, then what factors contribute to this negative impact? At the beginning of the research, field observations have revealed that some negative impacts (namely engraving in the rocks, painting or spraying on the rocks and destruction of natural rock shapes) have similar localization patterns: they are located directly on hiking trails in clearly visible places, but in passages that are less synoptic—so there is a lack of social control because it is easy to hide in the rocks. In addition, these were geosites, which are more visited by tourists, who at first glance are not typical nature lovers—they are very noisy, inappropriately dressed in nature, often drink alcohol along the way, etc. Based on these observations, two hypotheses were developed:

(a) The occurrence of negative impacts depends on the structure of visitors according to their attitude to vacation, expectations and motivation to visit the geosite.

(b) The occurrence of negative impacts depends on the distance of the nearest mass tourist facility, as negative impacts occur more often during some periods of the daytime, when geosites are less visited (morning, evening).

Confirmation or refutation of these hypotheses is discussed in this paper.

2. Materials and methods

2.1. Region

The area of interest for analysis is the region of northern Bohemia, which is located in the northernmost part of the Czech Republic, which is a country in Central Europe. There are a number of areas of sandstone rocks in the region of northern Bohemia, the most important and best known of which are two: The Bohemian Switzerland National Park and the UNESCO Global Geopark Bohemian Paradise (see Figure 1). Geologically, both regions are connected by the same origin, namely the sedimentary space of the Bohemian Cretaceous Basin, which originated in the Upper Cretaceous in a single sedimentary cycle (Cenomanian to Santonian) [17]. Sedimentation created several hundred meters' thick layers of sandstone, which were then modelled by erosion into interesting geomorphological shapes.

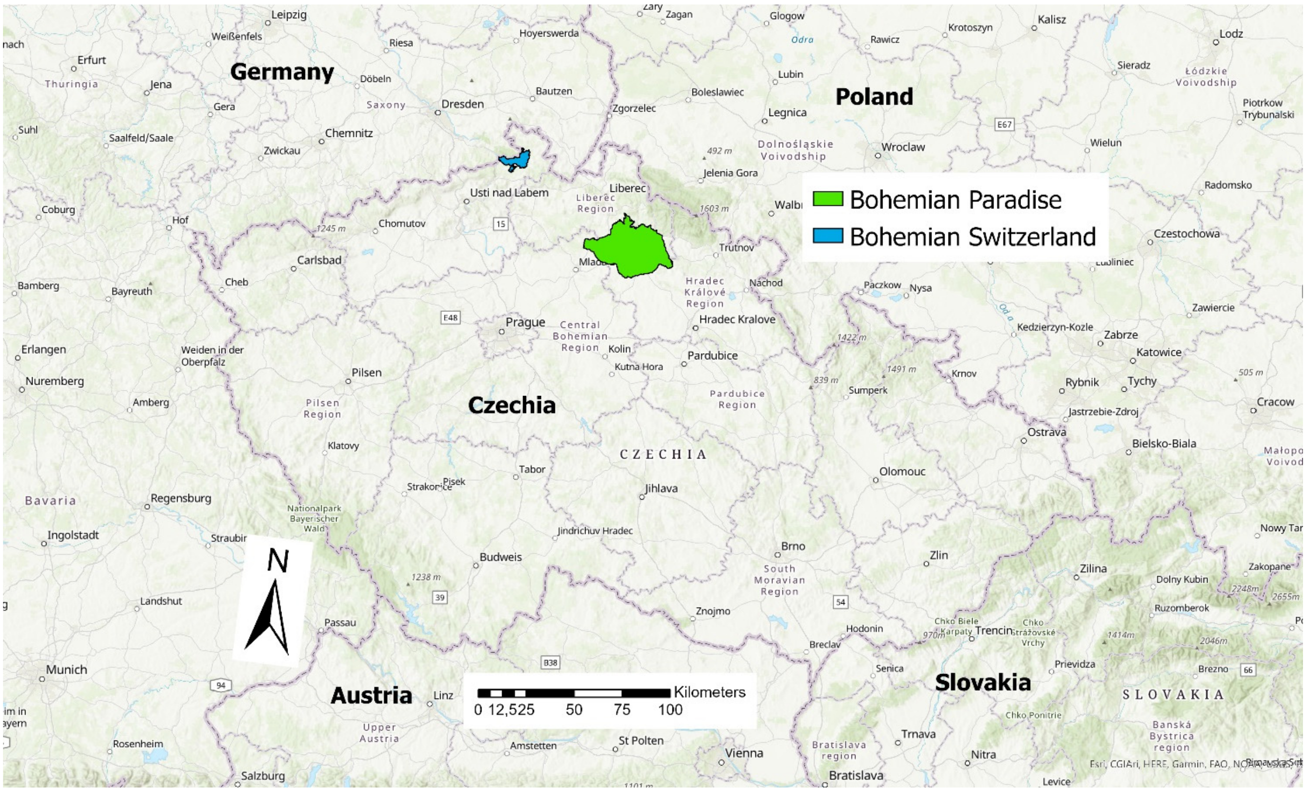

Figure 1. Location of the studied regions within Central Europe.

Bohemian Switzerland National Park is one of the four national parks in the Czech Republic. Most of its territory consists of a 350–420 m thick body of quartzose sandstones, which from a geological point of view was deposited in a relatively short time of less than 3 million years [19] (see Figure 2). The National Park was declared in 2000, the main subject of protection are unique sandstone formations and their habitat (Figure 3A). The most famous rock formation is Pravčická brána (Figure 3B), which is the largest sandstone rock gate in Europe [19]. Among the most visited tourist destinations in the national park are also the gorges of the river Kamenice (Figure 3C), which are visited annually by more than 400,000 tourists [16]. The popular tourist destinations include the

Šaunštejn rock castle (Figure 3D), which, however, is one of the most damaged localities by tourists. The national park administration even had to temporarily ban entry before improving the security of the hiking trail.

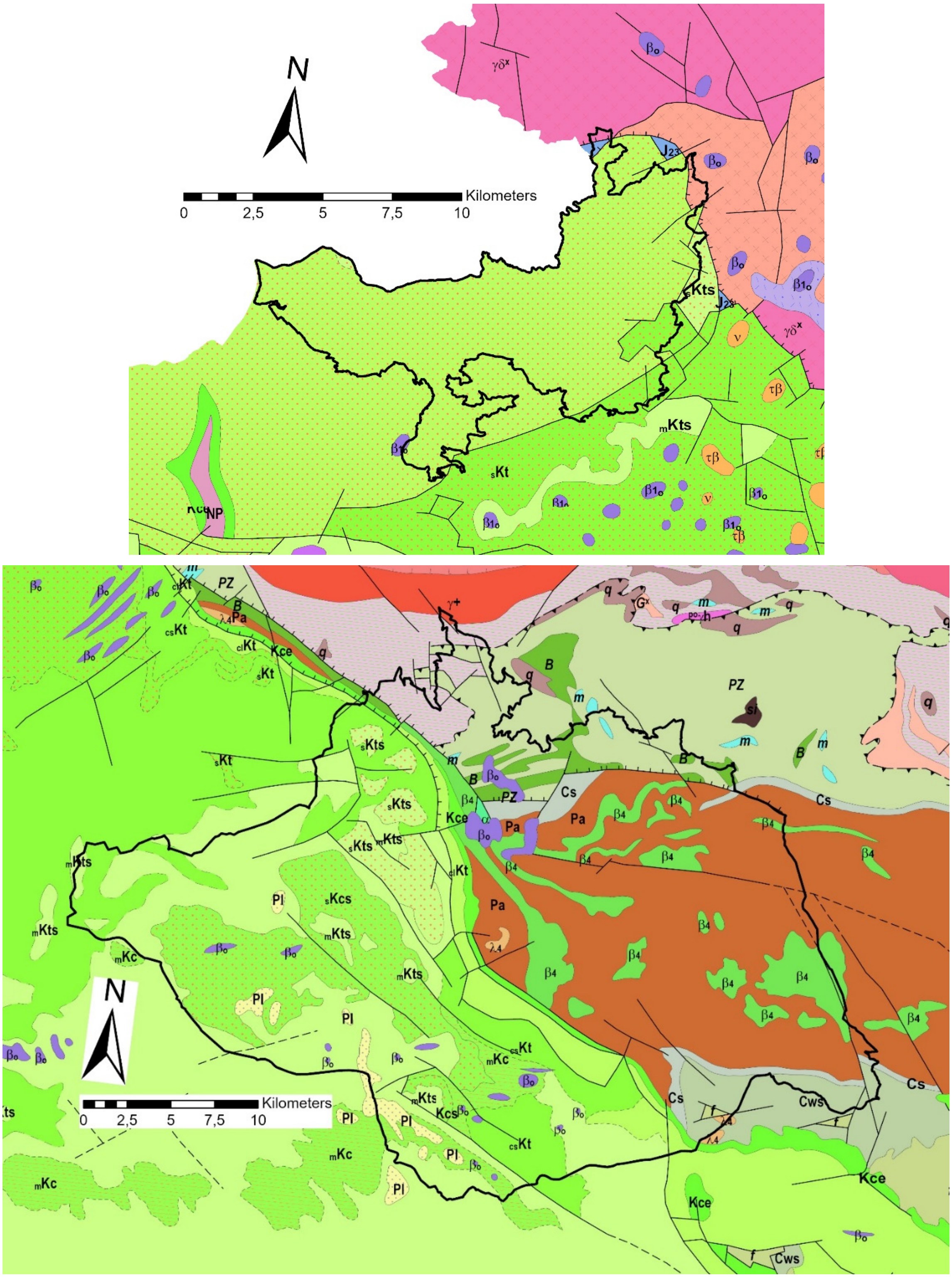

Figure 2. Geological map of Bohemian Switzerland (up) and Bohemian Paradise (down) [18].

TECTONIC LINE

- inferred major (nappe) thrust
- observed thrust
- inferred fault
- observed fault

CONTACT

- inferred boundaries of units and rocks
- observed boundaries of units and rocks
- lithological and petrological transitions

GEOLOGICAL UNIT

Terrestrial Paleogene and Neogene of the Bohemian Massif and the Carpathians - Cenozoic

PLIOCENE

Pl — sands, gravel, clays

Paleogene and Neogene of the Bohemian Massif - Cenozoic

PALEOGENE and NEOGENE

τβ — leucocratic trachybasalts, trachyandesites, trachytes, undifferentiated trachytic volcanics, intrusive trachytic breccias

ν — phonolites

β_o — olivine alkaline basalts and basanites, olivine foidites, limburgites, melilitic olivine-bearing rocks, subvolcanic basaltic breccias, altered olivine basaltic rocks (undated individual intrusions and effusions)

$\beta 1_o$ — olivine alkaline basalts and basanites, olivine foidites, limburgites, melilitic olivine-bearing rocks, subvolcanic basaltic breccias, altered olivine basaltic rocks

Mesozoic of the Bohemian Massif (predominantly marine)

UPPER CRETACEOUS (Coniacian–Santonian)

$_s$Kcs — quartzose sandstones, with lesserclayey-silty sandstones

$_m$Kc — calcareous claystones and marlstones with sandy intercalations

UPPER CRETACEOUS (Upper Turonian–Santonian)

$_s$Kts — quartzose sandstones,fine-grained clayey sandstones to siltstones

$_m$Kts — calcareous claystones and marlstones

UPPER CRETACEOUS (Middle–Upper Turonian)

$_s$Kt — quartzose and feldspathic sandstones, partly clayey or calcareous

$_{cs}$Kt — calcareous and clayeyfine-grained sandstones

UPPER CRETACEOUS (Lower–Upper Turonian)

$_d$Kt — calcareous claystones, marlstones, with lesser clayey limestones

$_{qs}$Kt — quartzose sandstones

UPPER CRETACEOUS (Cenomanian)

Kce — terrestrial fresh-water to marine claystones, siltstones, sandstones, and conglomerates

JURASSIC (Dogger–Malm)

J23 — limestones, dolomites, sporadic sandstones

Paleozoic of the Bohemian Massif

LOWER PERMIAN (Autunian)–± UPPER CARBONIFEROUS (Stephanian C)

Pa — red and grey terrestrial mudstones, sandstones, arkoses, conglomerates, coal beds

UPPER CARBONIFEROUS (Stephanian B)

Cs — red and grey mudstones, sandstones, arkoses, conglomerates, coal beds

UPPER CARBONIFEROUS (Westphalian±Cantabrian±Barruelian)

Cws — red and grey mudstones, sandstones, arkoses, conglomerates, coal beds

CAMBRIAN–LOWER CARBONIFEROUS (undifferentiated)

PZ — slightly metamorphosed siliciclastic sediments, locally intercalated with marble and metavolcanics

PRECAMBRIAN AND/OR PALEOZOIC, UNDIFFERENTIATED

f — phyllites (of chlorite, biotite, and possibly garnet grade)

g' — gneisses and migmatites subjected to retrograde metamorphism

Neoproterozoic

NEOPROTEROZOIC

NP — shales, greywackes (rhythmic alternation, flysch facies), intercalations of black shales, volcanics, carbonate sediments, very slightly to strongly metamorphosed

Intercalations in Precambrian and Paleozoic

PRECAMBRIAN UNDIFFERENTIATED

q — quartzites

si — cherts

m — marbles

Precambrian and Paleozoic Volcanics and Metavolcanics

PALEOZOIC (Upper Carboniferous–Permian)

λ4 — indurated rhyolite and dacite flows and tuffs

β4 — indurated basalts, basaltic andesites, and their alkaline equivalents and tuffs

PRECAMBRIAN and PALEOZOIC

α — metaandesites and alkaline metaandesites (porphyrites, keratophyres)

B — amphibolites, garnet amphibolites

VARISCAN INTRUSIVES

γ+ — rare-element-rich and tourmaline-bearing granites

$^{po}\gamma h$ — porphyritic amphibole-biotite and biotit-amphibole granites

INTRUSIVES OF PRE–VARISCAN OR UNKNOWN AGE

G^x — muscovite-chlorite, muscovite-chlorite-biotite, two-mica and biotite metagranites to metagranodiorites and orthogneisses

λ^x — biotite and two-mica granites and granodiorites, locally deformed and metamorphosed

$\lambda\delta^x$ — biotite and amphibole-biotite granites and granodiorites, locally deformed and metamorphosed

Figure 2. Continued.

Figure 3. Bohemian Switzerland National Park. Description in the text.

A closer look at the tourist map (Figure 4) shows that the territory of the national park consists mainly of forest stands in dramatically modelled sandstone rocks. The only village in its territory is Mezná, which is, however, an important tourist destination. However, due to the great development of tourism in the region, virtually every village offers a wide range of accommodation, like camping, guesthouses and hotels. In Figure 4, the geosites are marked with the purple numbers on which the research took place: 1—Pravčická brána, 2—Kamenice River gorges, 3—Šaunštejn, 4—Jetřichovické stěny, 5—Černá brána, 6—Brtnický hrádek, 7—Kinského vyhlídka. A number of hiking trails pass through the territory of the national park, which are marked with coloured lines in the figure (yellow, red, blue, green). On the German side of the border is the Saxon Switzerland National Park, which protects the north-western part of this valuable area.

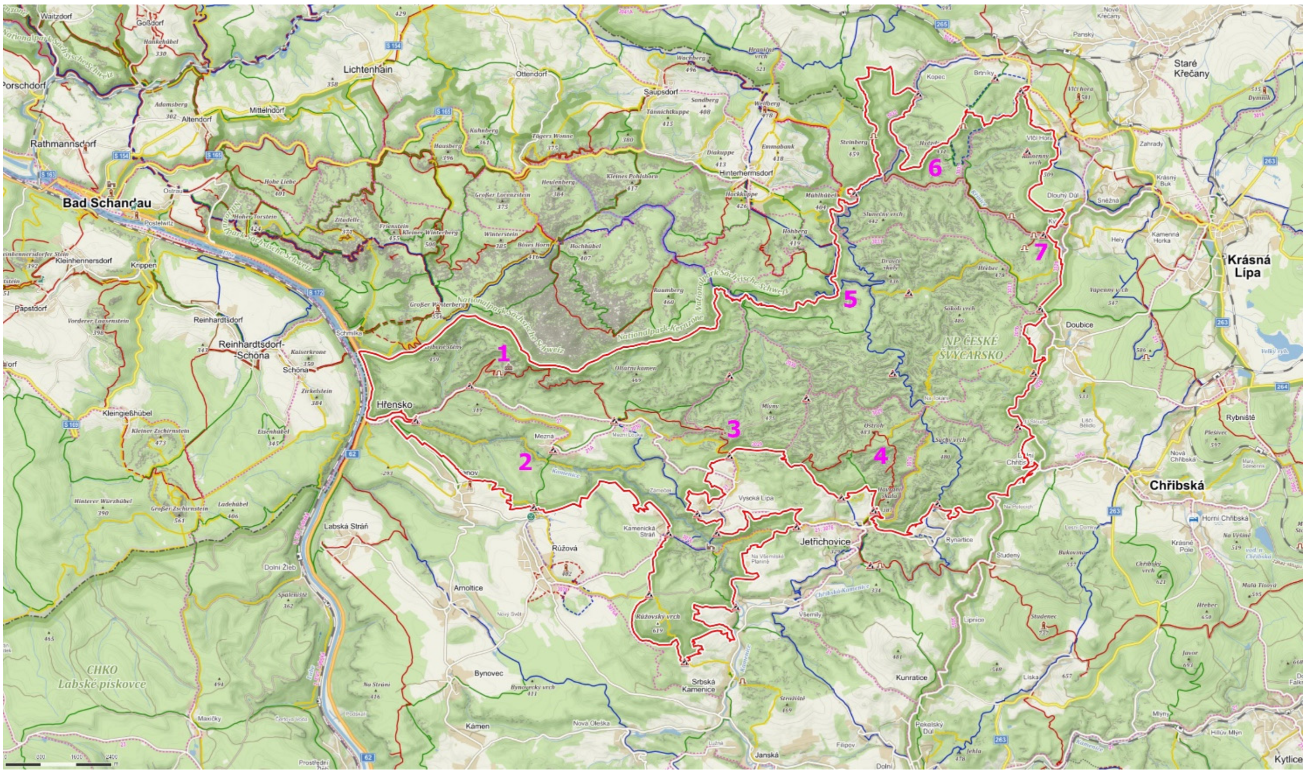

Figure 4. Geosites of the Bohemian Switzerland National Park. Description in the text. Background map: Mapy.cz.

Bohemian Paradise is a region that was declared the first Protected Landscape Area in the Czech Republic in 1955. In 2005, Bohemian Paradise was included as the 25th geopark in the network of European geoparks. In 2010, it was one of the two founding members of the Czech network of national geoparks, and in 2015 it became the only Czech member of UNESCO Global Geoparks [20]. The Bohemian Paradise Geopark is an area much more geologically heterogeneous than the Bohemian Switzerland National Park. In addition to the Cretaceous sandstones, there are also sedimentary rocks from the Palaeozoic, Mesozoic and Cenozoic, volcanic rocks of the Palaeozoic and Cenozoic and a number of metamorphic rocks (see Figure 2). There are many deposits of minerals and fossils and many caves. However, the most visited tourist sites are areas of sandstone rocks. The largest areas of rocks in the geopark are Hrubá skála (Figure 5A) and Prachovské skály (Figure 5B). The rocks along the tectonic line of the Lusatian Fault are also very attractive, such as Malá skála (Figure 5C). The region has been inhabited since prehistoric times and there are a number of cultural monuments, including rock castles, e.g. Drábské světničky (Figure 5D).

Figure 5. UNESCO Global Geopark Bohemian Paradise. Description in the text.

As the territory of the Bohemian Paradise Geopark is very large (833 km^2), the map of the territory in Figure 6 cannot be as detailed as in the previous case. In general, however, it is a region with a very dense network of hiking trails, even compared to the rest of the Czech Republic, which has the densest network of hiking trails in the EU [20]. Tourism in this region has a long tradition dating back to the 19th century. The designation "paradise" is intended to evoke the natural and cultural-historical beauties located here. Accommodation capacities are located throughout the geopark, but are concentrated in its south-western part, where its most attractive part is located—sandstone rocks. The figure again shows the geosites where the research took place: 1—Hrubá skála viewpoints, 2—Hrubá skála gorges, 3—Prachovské skály, 4—Drábské světničky, 5—Klokočské skály, 6—Besedické skály, 7—Malá skála, 8—Podtrosecká údolí.

Both studied regions are among the most visited rural areas in the Czech Republic and are an important source of income for local entrepreneurs. In addition to natural beauty, there are many other recreational opportunities, such as visiting cultural monuments, swimming pools and lakes, wellness, gastronomic tourism, adventure programs, etc. However, even tourists, whose primary goal is not to discover the beauties of nature, will go to the most famous natural tourist destinations in the area. This can then be a potential source of unwanted behaviour in protected areas.

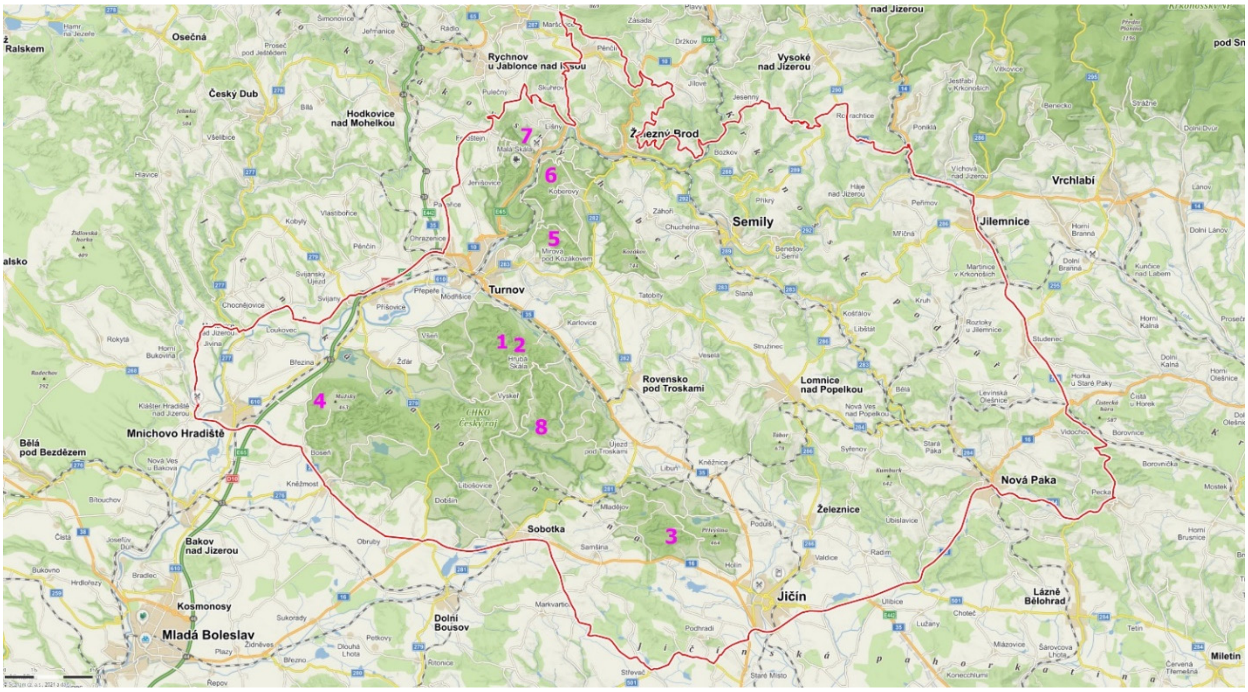

Figure 6. Geosites of the UNESCO Global Geopark Bohemian Paradise. Description in the text. Background map: Mapy.cz.

2.2. Rock damage

Negative impacts damaging nature in areas of sandstone rocks can be divided into the following categories:

(a) engraving in the rocks
(b) painting or spraying on the rocks
(c) destruction of natural rock shapes
(d) other types of vandalism
(e) pollution by garbage and excrements

Within the article, only the impacts (a)–(c) were analyzed, as they directly affect the rocks and have similar localization patterns. Other types of vandalism (d; damage to tourist infrastructure and biota, such as damage to hiking trails and information signs, tree engraving, breaking branches, etc.) is dependent on the presence of tourist infrastructure, as it usually has less intensity in localities where tourist infrastructure does not exist. Pollution by garbage and excrements (e) usually surrounds the main tourist routes, where most visitors move. Both impacts (d, e) are not concentrated in areas of sandstone rocks, but are present throughout, so they were not included in the analysis.

The first type of negative impact included in the analysis is rock engraving (Figure 7A). This is the most common type of rock damage, in some localities hundreds of them were counted. The content of these engravings are mostly simple messages and slogans, hearts with initials, names of people and dates when they were here, recently there have even been advertisements for websites and services, etc. The great prevalence of this negative impact is related to the fact that creating them in soft sandstone rock is a matter of a few minutes. All you need is a sharp end of a dead branch or any other durable elongated object.

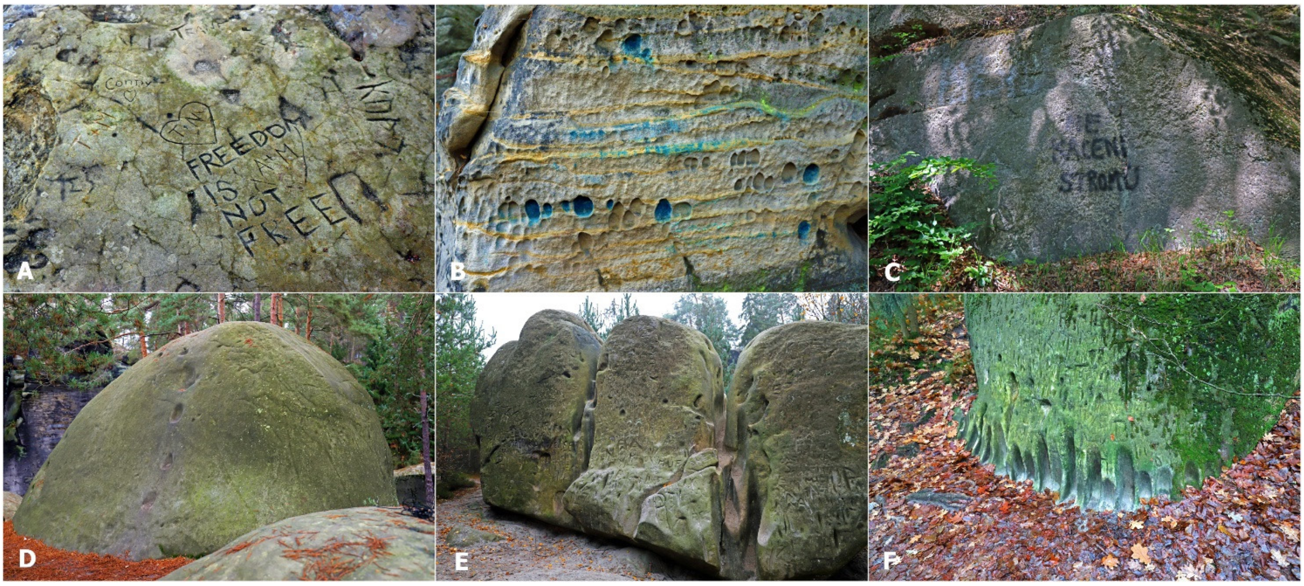

Figure 7. Examples of different types of rock damage. Description in the text.

The second negative impact analysed is painting and spraying on rocks. Painting can include various inscriptions, pictures, abstract shapes or honeycomb colouring (Figure 7B). Spraying usually involves inscriptions and slogans, signatures ("sprayer tags") and mostly poor attempts at graffiti (Figure 7C). The sad fact is that some of the paintings were obviously created by children (children's motifs, low height, etc.). That is, a group that should be experiencing environmental education lessons at school or kindergarten. Spraying is an impact that has only been present in rocks for the last 20 years, but its "popularity" is growing.

The third negative impact analysed is the deliberate destruction of natural rock shapes. This may include activities to entertain visitors, such as creating slides on sandstone boulders (Figure 7D), creating larger and wider stands and holds, gradually destroying the original shape of the rock (Figure 7E), or simply activities to ward off boredom, such as rubbing a rock edge with a shoe (Figure 7F). Some cases have arisen over years of disregard for the rules of nature reserves, where visitors have been climbing boulders along tourist paths for decades, which has led to their destruction. However, many cases are the result of the arrogance of some individuals, who are able to ruthlessly destroy the geological and geomorphological heritage that has developed over many millions of years in a matter of tens of minutes.

The analysis did not distinguish which kind of observed negative impact was involved, simply because it was sometimes a combination of them. In general, the ratio (a):(b):(c) was about 80:5:15.

2.3. Data and methods

The data used in the analysis come from several sources. The first of them is a field survey, the aim of which was to map the above-mentioned negative impacts in the field. For this purpose, 15 localities were identified, which are among the most visited geosites in both regions, and a square of 500 × 500 m was marked here, where mapping took place. This square typically included the core area of the geosite. The whole area of the geosite was not used for the analysis, but only this selected square, so the results are comparable—some geosites are significantly larger than others.

In the area of the square, the frequency was counted and the severity of negative impacts was evaluated, which resulted in an evaluation on a scale of 1–5, based on Table 1. The evaluation is based on two variables: the absolute number of recorded cases and significance of damage—the influence of these cases on the most valuable parts of geosites. The second variable is whether only less valuable rocks are damaged (smaller boulders by the road, common walls outside the main view lines), or even geomorphologically and aesthetically valuable parts (walls with honeycombs, the largest rock units, parts in the main view lines). To some extent, of course, this is a subjective assessment, for this reason, only a five-item scale was used.

Table 1. Rock damage assessment system.

Result	Number of cases	Significance of damage
1	0–10	A small number of cases.
2	11–50	Only less valuable parts are damaged.
3	11–50	Damaged even more valuable parts.
4	51 and more	Damaged mainly less valuable parts.
5	51 and more	Serious geosite damage.

Other data obtained in the field were data on the average daily number of visitors at 15 selected localities. In this case, for the consecutive 7 days in July (high season), visitors were counted between 6 am and 10 pm. The census was performed manually; the resulting value was the arithmetic mean of these seven days.

The third source of data from the field is interviewing visitors (a total of 2265), which took place again at 15 selected localities. This was not done using a questionnaire survey, which is time consuming, but by a method of selecting cards with key terms. The interviewer had 24 cards spread out on the camping table, on which the following terms were written: vacation, relaxation, rest, fun, family, friends, trip, rocks, nature, landscape, cultural monuments, museums, forests and meadows, views, cycling, swimming, hiking, good food and drink, beer and alcohol, festivals, entertainment for children, social events, parties, exploring new places. The respondent was first asked to pick up any number of cards that describe the things he wants to experience, see or visit on his vacation. Then the interviewer instructed him to rate each card he took according to significance on a scale of 1–10, where 10 is the most significant and 1 the least. The interviewer noted this information, then assigned a value of 0 to cards that the respondent did not select. The respondent could give more cards the same rating. In this way, data on the motivation and preferences of visitors to individual geosites were obtained, which was the basis for creating a typology of visitors.

The last source of data was data from the database of economic entities on public tourism facilities. These data are freely available in the database of the Czech Statistical Office [21]. The nearest mass tourism facility with an accommodation capacity of at least 100 people was found for each of the 15 selected localities. Then the distance between the centre of the marked square and this tourist facility was measured in GIS.

The first step in data processing is to create a typology of visitors based on the analysis of 24 variables obtained when interviewing visitors. K-means cluster analysis was used for this purpose. The resulting number of clusters was chosen on the basis of the rule on minimizing the loss function [22], when the number of clusters was selected at which the last time there was a significant decrease in the loss function.

In the final step, a correlation analysis was performed using Spearman's rank correlation coefficient ρ. The correlation was studied for the relationship between rock damage and hypothetical factors: the average daily attendance of a geosite in the high season, the distance to the nearest mass tourism facility (accommodation capacity over 100 people) and the share of selected types of tourists. This share was obtained by applying the result of the cluster analysis (typology of tourists) retrospectively to individual respondents at the localities. Thanks to this, it was possible to quantify the share of these types in each location and thus create a structure of visitors according to their preferences and motivation.

3. Results

The results of rock damage assessment of selected geosites are shown in Table 2. Geosites have been selected, which are among the most visited places in these tourist regions and at the same time evenly cover the territory of these regions. Two squares were selected in the Hrubá skála geosite, as their situations differ significantly, although they are close to each other and relatively equally visited. The situation of the Šaunštejn geosite corresponds to the state of 2019 and not to 2020, as in 2020 the geosite was partially closed (and some vandal paintings were removed). The results show that rock damage is a widespread impact that is present in virtually all monitored geosites with the exception of the Černá brána site. However, there are large differences in the extent of rock damage in both regions.

Table 2. Rock damage assessment of selected geosites.

Bohemian Switzerland geosites	Score	Bohemian Paradise geosites	Score
Pravčická brána	3	Hrubá skála viewpoints	3
Kamenice River gorges	3	Hrubá skála gorges	5
Šaunštejn	5	Prachovské skály	4
Jetřichovické stěny	2	Drábské světničky	5
Černá brána	1	Klokočské skály	2
Brtnický hrádek	3	Besedické skály	3
Kinského vyhlídka	3	Malá skála	4
		Podtrosecká údolí	2

Another variable monitored was the average daily number of visitors in the main season. This was determined by manual counting in the range of hours 6–22, its results are shown in Table 3. The results show that in the Bohemian Switzerland National Park there are two geosites that are significantly more visited than the rest of the territory, namely the Pravčická brána and the Kamenice River gorges. These two geosites are popular destinations for one-day bus trips from Prague, which bring crowds of tourists here. The numbers of tourists in the UNESCO Global Geopark Bohemian Paradise are more evenly distributed within the geosites, it is also a larger region. Both regions are comparable in terms of total tourist attendance of geosites.

Table 3. Average daily number of visitors (ADNV) in the main season of selected geosites.

Bohemian Switzerland geosites	ADNV	Bohemian Paradise geosites	ADNV
Pravčická brána	2915	Hrubá skála viewpoints	2737
Kamenice River gorges	2783	Hrubá skála gorges	2645
Šaunštejn	1621	Prachovské skály	2412
Jetřichovické stěny	1534	Drábské světničky	1705
Černá brána	693	Klokočské skály	760
Brtnický hrádek	562	Besedické skály	1382
Kinského vyhlídka	1347	Malá skála	1873
		Podtrosecká údolí	1716

Next variable entering the final analysis is the distance of the centre of the marked square from the nearest accommodation facility with a capacity of at least 100 people. This analysis took into account the fact that some accommodation facilities are artificially divided into two or more economic entities (e.g. one operates a guest house and one campsite). If these entities operate in one closed area, their accommodation capacity has been added together. The results are shown in Table 4.

Table 4. Distance of selected geosites from the nearest accommodation facility with a capacity of at least 100 people (DAF).

Bohemian Switzerland geosites	DAF [km]	Bohemian Paradise geosites	DAF [km]
Pravčická brána	2.86	Hrubá skála viewpoints	1.22
Kamenice River gorges	1.87	Hrubá skála gorges	0.64
Šaunštejn	1.51	Prachovské skály	1.09
Jetřichovické stěny	1.74	Drábské světničky	3.26
Černá brána	5.43	Klokočské skály	3.37
Brtnický hrádek	6.18	Besedické skály	1.49
Kinského vyhlídka	3.93	Malá skála	0.38
		Podtrosecká údolí	2.11

Data on the typology of tourists are the result of a cluster analysis using the K-means method, which was based on 2265 interviews with visitors. On average, there are 151 visitors per site. More interviews were given to geosites with higher ADNV, but at least 100 interviews were always conducted at a given locality. The result of clustering is 8 categories, which were named according to their defining characteristics as follows: nature lover, history lover, traveller, resting tourist, social tourist, active tourist, romantic, parent. Because it is not possible to present the complete results of the cluster analysis here due to the number of variables, these categories are characterized in a simplified form below:

(a) Nature lover (15.3% of all cases)—clearly focused on hiking in nature. Highest score from the offered cards: nature (8.9), rocks (7.3), forests and meadows (7.0), landscape (6.8), hiking (6.8).
(b) History lover (7.6%)—mainly focused on learning about historical monuments and local culture. In Bohemian Switzerland its share is only 2.3%, while in Bohemian Paradise it is one of the most widespread categories. Highest score from the offered cards: cultural monuments (7.1), exploring new places (6.7), museums (6.5), landscape (6.5).

(c) Traveller (9.2%)—focused on exploring new countries and regions. The most common category for foreign tourists. Highest score from the offered cards: exploring new places (7.4), vacation (6.6), landscape (6.5), cultural monuments (5.9), good food and drink (5.8).

(d) Resting tourist (22.8%)—mainly wants to relax on his vacation. Highest score from the offered cards: rest (7.6), relaxation (7.3), fun (7.2), swimming (7.0), good food and drink (6.8), friends (6.8), parties (6.7), family (6.5).

(e) Social tourist (17.1%)—the holiday is an opportunity to have fun with friends and meet new people. Highest score from the offered cards: fun (8.0), friends (7.9), beer and alcohol (7.6), parties (7.6), good food and drink (7.4), festivals (6.3), social events (6.1).

(f) Active tourist (5.1%) focused on movement in nature, experiences and sports. Highest score from the offered cards: hiking (6.9), rocks (6.6), landscape (6.2), cycling (6.1), views (6.1), exploring new places (5.8).

(g) Romantic (8.4%)—enjoys peace and quiet in nature, as well as the beauty of historical monuments. Highest score from the offered cards: landscape (6.5), nature (6.2), cultural monuments (6.1), rocks (5.8), forests and meadows (5.8), rest (5.5).

(h) Parent (14.5%)—focused on finding entertainment for children. Highest score from the offered cards: entertainment for children (7.8), family (6.5), landscape (6.3), good food and drink (6.2).

The typology described above is a certain mathematical simplification of reality, which is necessary in order to be able to quantify the influence of individual types of tourists on the presence of rock damage in the localities they visit. If there were a direct relationship between the number of visitors and the degree of damage to the rocks, the most damaged localities would be the Pravčická brána and Kamenice River gorges. However, this is not the case. For this reason, a structure of visitors according to the above types was created for each location. All the above-mentioned variables were then the basis for the last step of the analysis, correlation using Spearman's ρ.

The correlation results are shown in Table 5. Four statistically significant relationships were found, namely between rock damage and types of tourists: nature lover and romantic (negative), social tourist and resting tourist (positive). No other significant relationships were found even at $p < 0.05$. The interpretation of these results is discussed in detail in the following chapter.

Table 5. Correlation of the variable "rock damage" with other selected variables.

Variable	Spearman's ρ
ADNV	0.392
DAF	−0.512
Nature lover	−0.817*
History lover	0.013
Traveller	−0.106
Resting tourist	0.712*
Social tourist	0.773*
Active tourist	−0.149
Romantic	−0.718*
Parent	0.307

Correlations marked * are significant at $p < 0.01$.

4. Discussion

Before interpreting the results of the correlation analysis, it is first necessary to comment on the results of the rock damage assessment at individual localities. Based on the knowledge of the terrain, it can be stated that in general, the less damaged geosites include those where the visitor comes into less contact with the rocks—i.e. where he can see them below him (Klokočské skály), behind the water (Podtrosecká údolí), at a greater distance from the hiking trail (Jetřichovické stěny), or they are overgrown with vegetation (Černá brána). However, the reverse logic does not apply—the places where tourists weave between the rocks are not always damaged. The following have proved to be problematic localities: (a) important lookout points, where it is relatively easy for tourists to get directly to the rock; (b) smaller rock formations near major and more frequented rocks. In the first case, visitors have a desire to perpetuate that "they were here", in the second case they feel that no one is interested in these parts and they can do whatever they want here. The content of individual engravings on the rocks or the location of the damaged geomorphological shapes of the rocks also correspond to these conclusions.

The results of the correlation showed that potential factors average daily number of visitors and distance of selected geosites from the nearest accommodation facility with a capacity of at least 100 people do not have a statistically significant effect on rock damage. A statistically significant positive correlation was demonstrated in the categories of social tourist and resting tourist, and a statistically significant negative correlation in nature lover and romantic. Although correlation does not mean causality, it is true that the most damaged localities are among the favourite excursion destinations for visitors, who at first glance see their trip to the rocks as a supplement to drinking beer, swimming in lakes or evening entertainment in the camping. These visitors probably do not appreciate the purity and integrity of nature and more often behave ruthlessly. The negative correlation in the nature lover and romantic categories is largely due to the fact that these visitors are looking for quiet and intact locations, which may not be the biggest highlights. The larger share of these categories in geosites is therefore often the result of less interest of mainstream tourists in these sites.

Nature conservation authorities in both regions are aware of the poor condition of many geosites and are working to improve it. Damage to the rocks is often commented on by locals, who remember the times when the rocks were not as damaged as they are today. It is then necessary to ask whether both regions, from the point of view of the Butler's tourism area life cycle model [23–25], are not currently at a critical point where the damage to the site will increase so much that it will cease to be interesting. In addition, the current pandemic of SARS-CoV-2, when Czech tourists largely did not go on holiday abroad in 2020, may influence the decision-making of tourists, which they will want to compensate in the coming years. However, a drop in visitors would be a disaster for the local economy: both regions are among the rural peripheries [26], where many shops and services exist only thanks to tourists. In a situation where successful urban regions are trying to compete with rural areas also in geotourism [27], weakening their position of top tourist destinations would mean great complications for both regions.

5. Conclusions

The area of sandstone rocks belongs to the most valuable geoheritage in the Czech Republic [14–16]. The value of these geosites is also documented by the highest degree of Czech nature protection—a national nature reserves. In addition, the Bohemian Switzerland region is a national park [19], the Bohemian Paradise region is a UNESCO global geopark [20]. Nevertheless, this highest level of protection cannot prevent various types of rock damage caused by the reckless behaviour of visitors [14]. Given that millions of years of unique geotope development may be wasted in a few years of reckless damage, the geoheritage deserves special care [28]. For this purpose, a special geoheritage and geodiversity management strategy [29] would need to be developed, which would give clear guidance on what measures to take to prevent rock damage.

This article aimed to identify the factors that influence rock damage in the above-mentioned regions. The proposed strategy should then focus on these factors. Two main hypotheses were mentioned in the introduction of the article: that (a) the occurrence of negative impacts depends on the structure of visitors according to their attitude to vacation, expectations and motivation to visit the geosite; and (b) the occurrence of negative impacts depends on the distance of the nearest mass tourist facility. While the first hypothesis was confirmed, the second was rejected.

The research presented in this article identify two risk groups of visitors, whose increased presence in the geosite means an increased threat to this geosite: social tourist and resting tourist. For social tourist, vacation is an opportunity to have fun with friends and meet new people. These visitors often look for social events, festivals and parties, consume alcohol during the day and are not very interested in nature or culture. Resting tourist mainly wants to relax on his vacation and trips to nature perceives as a supplement to his recreational activities. By identifying the places where these types of tourists are concentrated, it is possible to estimate which geosites are most endangered by rock engraving, painting, spraying and destruction of natural rock shapes. The second type of measure should be targeted education of these types of tourists to understand the value of the surrounding geoheritage [11,30–32]. The greatest enemy of any kind of heritage protection is human ignorance.

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Conflict of interest

The author declares no conflicts of interest in this paper.

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