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METHODOLOGY OF GEOSITES' TOURIST ASSESSMENT AND GEOTOURISM MAPPING (EXAMPLES OF ŠTIAVNICKÉ VRCHY, SLOVAKIA)

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Abstract: Štiavnické vrchy are a geomorphological region of Slovakia, the landscapes of which attract the attention of tourists. The main goal of the article is to apply a methodology for assessing the tourist attractiveness of geosites according to scientific, aesthetic, cultural-historical, socio-economic, ecological, safety values, based on the works of leading geomorphological scientists in Europe. Geosites with the most pronounced characteristics were selected as an example for each evaluation criterion, which differ significantly from objects that do not have such characteristics and influence the final assessment of the overall tourist attractiveness. The existing methodology has been supplemented with a criterion for the safety of tourists during hikes. Based on the obtained assessments of tourist attractiveness on the corresponding map geosites with high, medium and low tourist attractiveness were identified as the main result of the work and recommendations were given to improve this indicator for sites with low attractiveness through the organization of artificial attractive objects. Such activities include the organization of forest arboretums, various museums, gastronomic and equestrian tourism facilities. It is proposed to take morphometric indicators into account for the tourist assessment of geosites, as they determine the visibility, attractiveness, diversity and passability of the territory, as well as the microclimatic conditions of the area. It was concluded that further tourist development of sites with low tourist attractiveness depends on economically labor-intensive measures to clear and develop tourist trails, which are currently characterized by unsatisfactory conditions. However, the implementation of such actions will be useful in the long term and will ensure sustainable development of the territory. The study concludes that structured evaluation and thematic mapping can guide sustainable geotourism development. These findings can influence geotourism strategies in other regions.

Keywords: geosite assessment, geotourism mapping, Štiavnické vrchy, tourist value, GIS, Slovakia

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INTRODUCTION

A geosite is a specific location on Earth that holds significant geological or geomorphological interest, making it valuable for scientific study, education, or tourism. These sites have a rare and valuable geological, geomorphological, cultural-historical, and natural phenomenon or complication that has outstanding scientific, aesthetic, and cultural-historical value and, while having the appropriate interpretive tools and infrastructure, provides public visiting conditions for visitors (Prosser et al., 2018; UNESCO, 2023a; UNESCO, 2023b; Štrba et al., 2024; Carrión-Mero et al., 2024).

Štiavnické vrchy are a unique volcanic mountain range in the central part of Slovakia, which is rich in beautiful mountain peaks, deciduous forests, fresh lakes, hot springs, and architectural, archaeological, and cultural-historical sites. More than 150 geosites of geological, geomorphological, tectonic, stratigraphic, hydrogeological, petrological, and mineralogical profiles are located in an area of more than 600 km² in the territory of the Štiavnické vrchy. There are no studies on the geotourism assessment of geosites to date, despite their abundance in the Štiavnické vrchy, there is no ranking of these objects according to their attractiveness for tourist visits, and there are no cartographic materials with a geotourism focus. The scientific literature on the topic of geoheritage and geoconservation in the territory of the Banská Štiavnica Geopark contains data on the development and availability of georoutes (Palgutova et al., 2024). It raises issues of geoeducation of tourists by installing information panels on geotourist routes (Palgutova et al., 2023). Among the popular scientific literature on tourism in the study area we would like to highlight the book «Štiavnické vrchy» by Albert Kelemen (Kelemen, 1986) and the book «Štiavnické vrchy – Slovenské stredohorie» by Daniel Kollár (Kollár & Lacika, 2004), which in narrative form acquaint the reader with the natural wealth of the area and offer a variety of tourist routes of varying degrees of difficulty, describing the main attractions and providing scientific information on geological and geomorphological monuments in an accessible journalistic form. Employees of the Dionýz Štúr State Geological Institute published the book «Geotopes of the Banská Štiavnica geopark» in 2023, which contains information on 103 geosites of the Banská Štiavnica region, which extends beyond the Štiavnické vrchy. The geological component of the indicated geosites is well described in this book, however, in all sources of literature, both scientific and journalistic, there is no data on their geotourist assessment, and there are no cartographic materials. Nevertheless, the relevance of geotourism assessment always

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remains high, since this procedure is necessary not only to convey information to tourists about the most striking geosites of the territory but also for effective development and management, as well as for the protection of geological heritage (Suzuki & Takagi, 2018). The growing scientific interest in geoheritage has led to the development of numerous assessment methods.

According to Reynard (Reynard et al., 2007) most of them can be divided into several groups. Early assessment models favored the assessment of scientific values only (Grandgirard, 1999; Coratza & Giusti, 2005; Tessema et al., 2021; Mucivuna et al., 2022; Sutiksno et al., 2024). With the growing interest in geoheritage in scientific circles, socio-cultural attributes were also noticed, so later assessment models extended the assessment to other values in addition to the scientific category. They emphasize the need for protection and point out potential threats (Bruschi & Cendrero, 2005), evaluate socio-economic and geocultural values (Panizza, 2001; Migoń, 2024), management values (Pereira et al., 2007), quantitative (tourist and exploitation values) and qualitative criteria (Pralong, 2005), ecological (Bollati et al., 2015; Cocean & Cocean, 2017), Bussard & Giaccone, 2021) aesthetic (Ha & Yang, 2019; Le et al., 2019; Urbis et al., 2019), historical (Reynard, 2020; Kubalíková & Kirchner, 2016), cultural (Gordon, 2018a; Gordon, 2018b; Reynard & Giusti, 2018; Pijet-Migoń & Migoń, 2022), economic (Pérez-Álvarez et al., 2016) and other categories (Ivanović et al., 2023; Comănescu et al., 2025).

The purpose of this article is to assess the tourist attractiveness of geosites in the territory of the geomorphological region Štiavnické vrchy in Slovakia for such categories as scientific, aesthetic, cultural-historical, ecological, socio-economic, as well as from the point of view of the safety of tourists during hiking or travel. Each type of value will consist of certain evaluation categories, the compilation of which will be made based on the scientific works of leading geomorphologists in Europe. The evaluation category will be assigned a certain score through expert assessment depending on their severity.

As a result, each geosite will receive a total tourist attraction score as the arithmetic average for each category divided by the total number of values. In this article, for the most complete disclosure of the meanings of a particular value, 6 geosites with the most pronounced characteristics will be presented as an example. As a result, it is planned to compile a map of the general tourist assessment of geosites on the territory of Štiavnické vrchy, will allow identifying sites with varying degrees of tourist attractiveness. Such zoning will highlight the problem of a shortage of geological heritage objects in certain areas, which will encourage the search for possible alternatives to increase the overall tourist attractiveness of such territories by organizing artificial attractive objects. Here it should be understood that the creation of artificial attractive objects will not solve the problem of tourists' access to possible geosites, and therefore a further problem in the development of such territories is the arrangement of trails and the development of tourism infrastructure, which requires appropriate efforts on the part of local governments and European Union tourism development organizations. Ultimately, solving the identified problems will contribute to unlocking the tourism potential of geosites and the economic prosperity of the region.

STUDY AREA

The Štiavnické vrchy are a volcanic mountain range in southern central Slovakia, considered one of the most attractive in the country. They are part of the Inner Western Carpathians and the Slovenské stredohorie.

Figure 1. Location of Štiavnické vrchy on the territory of Slovakia (A) and their geomorphological zoning (B) (Source: Zhyrnov, 2024)

The area belongs to Štiavnické vrchy Protected Landscape Area. They are bordered by the Kremnické vrchy in the north, Pliešovce and Krupinská kotlina in the east, Podunajská pahorkatina in the south, and Pohronský Inovec, Vtáčnik and Žiarska kotlina in the west (Kollár & Lacika, 2004). Štiavnické vrchy are divided into ten geomorphological regions: Breznické podolie, Hodrušská hornatina, Kozmálovské vŕšky, Prenčovská kotlina, Sitnianske predhorie, Sitno, Skalka, Slovenská brána, Vyhnianska brázda and Štiavnická brázda (Figure 1) (Mazúr et al., 1986).

The highest part of the Štiavnické vrchy is Sitnianska vrchovina with the highest peak Sitno, (1009 m) which protrudes impressively above the outskirts of the mountain range and from which magnificent distances are visible. It is a conspicuous mountain towering above the surrounding landscape which offers a panoramic view of wide environs. The Sitno mountain is the product of the lava flow. Its top plateau is delimited by rock faces in places 80 m tall. It is a subject of many legends and folk tales. Perhaps the most popular legend is that its entrails shelter the Knights of Sitno (Kollár & Lacika, 2004).

The lower part of the Sitnianska vrchovina Upland is dissected into the system of parallel ridges and valleys oriented in the direction of the meridian. The ridges are long and flat. Isolated elevations protrude from a comparatively large plateau. The tallest of them (the Holík mountain – 784 m) exceeds 700 m above sea level.

The valley is also long and not too branched. Most of them proceed as far as the edge of the mountain range and continue as a parallel valley network of the Ipel'ská pahorkatina hillland. The largest valley created by the Štiavnica brook in the vicinity of Prenčov widens into the small Prenčovská kotlina basin. The massif of Sitno falls abruptly to the Štiavnicka brázda furrow, which is the largest depression in the Štiavnické vrchy. The wide depression stretches into the place where the central crater of the Štiavnica stratovolcano once existed. The depression is linked to softer rocks, which are more prone to erosion than the harder vulcanite. The surface of the Štiavnická brázda furrow is broken into tiny hills which are the heaps of dead, remains of the past intensive mining in wider environs of the town Banská Štiavnica.

A conspicuous dominant of the furrow is the cone-shaped mountain of Kalvária (749 m) which was old-modelled by preparation of the volcanic chimney of an extinct volcano subsequently filled by the hardened basalt lava. A similar basalt form also exists in the locality of Kysihýbel (Kollár & Lacika, 2004).

The most dissected relief is that of the Hodrušská hornatina highland, which occupies the western part of the Štiavnické vrchy. Its forms are varied due to a comparatively large altitude difference between the deep incised valleys and high ridges. The elongated ridge west of Banská Štiavnica is the tallest and most attractive for hikers. Two grassy tops dominate in this ridge: Paradajs (839 m) and Tanád (839 m). They are also visited for the nice panoramic view they offer. The elongated ridge has two parallel side ridges which separate a system of deep valleys. The northernmost of the trio of large valleys in the central part of the Hodrušská hornatina highland is the valley of Teplá with interesting rock forms. The spa village of Sklené Teplice displays some travertine forms linked to the local fairly hot thermal springs. The rocks that exist here on a volcanic substrate also occur in the locality Kamenný Jarok. The best known of them is the Szabóova skala rock which stands as a "sentry" at the entrance to the valley. In the west of the valley of the Teplá River is the ridge with the dominant Zlatý vrch (850 m) also known as Kolberg. On the opposite side of this ridge, the slopes abruptly fall to the deep Vyhnianska dolina valley. Interesting geomorphologic features are concentrated in the environs of the old mining village Vyhne. The Vyhniansky travertine, for instance, is right in the village. It is the travertine hillock standing next to the spring of much mineralized water which oozes here from the not volcanic substrate. On the opposite side of the valley is the Kamenné more (The Stone Sea) consisting of a large number of rhyolite stone blocks. With its area of 13 hectares, it is the largest of its kind in the territory of the volcanic Carpathians (Kollár & Lacika, 2004).

South of the Vyhnianska Dolina valley is the mountain ridge culminating in the Banský vrch (866 m.) also called Kerling. Below it, in the south is the Hodrušská dolina valley, which is dotted by traces of mining activity carried out here in the past. Houses of a couple of mining villages. Dolné Hámre and Banská Hodruša, now joined into one – Hodruša-Hámre, stand along the whole valley. South of the village is a comparatively straight ridge with the tallest mountain of Baňa (760 m) which separates the Hodrušská and Richňavská dolina valleys. The shape of the southern part of the Hodrušská hornatina highland is that of a long ridge with mountains that do not exceed a sea level altitude of 700 m. The south-western end of the Hodrušská hornatina highland is the Slovenská brána gate where the Hron River leaves the Carpathian Mountains behind and enters the Podunajská nížina lowland. The Skalka is another, though lower and less dissected elongated ridge along the eastern edge of the Štiavnické vrchy mountains. In the north, the ridge forms a comparatively narrow mountain barrier between the deep Kozelnícka dolina valley in the west and the Pliešovská kotlina basin in the east. In the central part the erosive Studenská (Kolpašská) kotlina basin with the village of Banský Studenec and a couple of the Studenské jazerá lakes, interrupts the compactness of the Skalka. North-west of lakes towers the tallest mountain of this part of the ridge, the Skalka mountain (882 m) (Kollár & Lacika, 2004).

However, Štiavnické vrchy are rich not only in geological and geomorphological monuments. Here are the cleanest fresh lakes called tajchy. Tajchy are artificial water reservoirs in the Štiavnické vrchy. Most of them were built to provide energy for the silver mines of Banská Štiavnica in the 18th century. At their height, tajchy comprised a sophisticated system of 60 reservoirs, connected by more than 100 km of channels and tunnels. 24 artificial lakes still exist and serve recreational purposes. Because of their historical value, tajchy was proclaimed by UNESCO to be a World Heritage Site on 11 December 1993, together with the city of Banská Štiavnica and technical historical monuments in its surroundings. Among the most touristically attractive and large tajchy (tajchs) we can highlight Jazero Počúvadlo-Počúvadlo lake (Figure 2) Veľká Richňavská nádrž, Kolpašsky tajch in Banský Studenec, Hodrušky dolny tajch in Hodruša-Hámre, Veľký Vindšachtský tajch in Štiavnické Baňe, Rozgrund tajch in Banská Štiavnica, Bakomi tajch in Štiavnické Baňe, Beliansky tajch in Banská Belá. Hot springs and the unique Parenica cave are located in the resort village of Sklené Teplice, which is used for medicinal and recreational purposes (Kelemen, 1986).

Figure 2. Počúvadlo lake (Source: Authors fieldwork, 2024)

Among the attractive archaeological and architectural sites of Štiavnické vrchy it is worth highlighting námestie Svätej trojice, Starý and Nový zámok, Kalvária, hrad Glanzenberg, Žakýlsky hrad, Breznica hrad, kostol svätej Kataríny, hrad Marcus, hrad Sitno, kaštieľ Svätý Anton, Šášovský hrad etc. (Kollár & Lacika, 2004). Thus, the Štiavnické vrchy are a very attractive tourist area (the area is a strong tourist destination according general tourism-geography framing (Ionescu et al., 2017). They have a complex geomorphological and geological structure, and therefore are characterized by significant geodiversity and the presence of many geosites, the tourist assessment of which we will begin in this article.

METHODOLOGY OF THE WORK

The methodological part of the work on the tourist assessment of geosites in the territory of the Štiavnické vrchy consisted of three stages: preparatory, field, and office (Bilgiç et al., 2024; Zorlu et al., 2024; Li, 2025; Pál et al., 2025; Ghermandi, 2022; Wróżyński et al., 2024; Arnon et al., 2023; Li et al., 2024; Vandelli et al., 2024; Kubalíková et al., 2024; Olteanu et al., 2024; Cirillo et al., 2024; Lawrence, 2014). Specialized literature and tourist maps were analyzed in the preparatory stage. Field routes and preliminary overview of geosites during their passage were planned based on guidebooks by Albert Kelemen "Štiavnické vrchy" (Kelemen, 1986) Daniel Kollár, Ján Lacika "The Štiavnické vrchy Mts." (Kollár & Lacika, 2004) and a specialized publication of the Dionýz Štúr State Geological Institute edited by RNDr. Vlastimil Konečný, CSc. Ing. Patrik Pachinger "Geotopes of the Banská Štiavnica geopark: volcanism and structure of the territory" (Konečný & Pachinger, 2023). The tourist map "Štiavnické vrchy", 8th edition, scale 1:50,000 from VKÚ Harmanec (Mozolová, 2021) was also preliminarily studied. This map was subsequently scanned and used as a basis for digitizing the network of footpaths, cycle routes, roads, railways, hydrographic networks, and tourist infrastructure.

It should be noted that the number of geosites in the books and maps mentioned was smaller than those subsequently described and evaluated by the authors of this article during field research. The Mapy.cz program was also pre-installed on the smartphone, and a tourist map of the Štiavnické vrchy area was downloaded to enable offline operation.

All tourist routes were completed using this computer application. When a specific geosite was described, a location save mark was placed, which later made it possible to transfer all geosites saved in this way to cartographic material in the form of point objects. A paper evaluation journal for each geosite was also created at the preliminary stage, where evaluation scales were indicated for each evaluation category for expert evaluation.

The field stage included the direct passage of the routes described in the above-mentioned literature with the navigation program "Mapy.cz". 153 geosites were marked and described in this way during field research, which was marked with the "Save location" option in the "Mapy.cz" program. Each geosite was assigned a serial number and a corresponding name. Next, a direct expert tourist assessment of geosites was carried out according to 6 assessment categories: scientific, aesthetic, cultural-historical, ecological, socio-economic, and also a safety category. Each category consists of a certain number of evaluation criteria, which, depending on the degree of expression, were assessed with points from 0 to 1, where 0 reflects the complete absence of a certain characteristic, and 1 – the most pronounced characteristic of the criterion. The

final score for each criterion of a particular category was calculated as the arithmetic mean of the sum of all criteria divided by their number. The authors of this article acted as expert evaluators, provided that each assessment was given independently by each author without discussing personal preferences, thus, a certain reduction in the level of subjective attitude in the assessment of a particular geosite was achieved.

The first evaluation category used in the tourist evaluation of geosites was the scientific category. The scientific category plays a key role in the tourist assessment of geosites. Based on the fundamental recreational-and-aesthetical geomorphological research (Coratza & Giusti, 2005; Pralong, 2005; Pereira et al., 2007; Reynard et al., 2007; Rybár, 2010; Kubalíková, 2013) the conclusion can be made that scientific category of relief assessment can be formulated as follows:

1) Paleogeographical value (importance of the geosites for the Earth's history);
2) Representativeness (geosites' exemplarity);
3) Rareness (rarity of the geosite concerning a reference space);
4) Integrity (state of conservation of the geosite);
5) Diversity (number of different partial features and processes within the geosite).

We decided to evaluate this category to reveal its meanings using the example of a geosite with the most pronounced criteria. This was the Glanzenberg peak in the vicinity of Banská Štiavnica.

The aesthetic category of geosites is the most important stage of tourist assessment. According to the last research (Likhacheva & Timofeev, 2002; Kubalíková, 2013; Štrba, 2015) aesthetical assessment of the geosites as a natural object consists of such criteria:

1) Uniqueness of geosites: a) by the genesis; b) by the form and geographical location;
2) Uniqueness of geosites' surface appearance: a) dissimilarity on anything (fantastic plot); b) similarity to biological and architectural objects;
3) Architectonic and composition of geosites;
4) Visibility: a) outside view; b) visual exposure of the geosites from the object;
5) Exoticism (contrast degree);
6) Expressiveness (expressiveness degree of geosites);
7) Attendant effects: a) sounds – quiet (noise of waterfall, surf, echo…) b) warmth – coolness; c) brightness; d) color; e) illumination (at sunrise, sunset, by the light of the moon…);
8) Compatibility – combination with other elements of a landscape: with flora, fauna, hydrological objects, architectural objects;
9) Photogenicy (the favorite object of painters, and photographers);
10) Emotional perception: a) admiring; b) worship; c) feeling of privacy; d) feeling merge to nature.

We decided to evaluate this category to reveal its meanings using the example of a geosite with the most pronounced criteria. This is what happened to the Tanád peak in the vicinity of Banská Štiavnica city.

The cultural-historical category depends on an art event or a cultural custom about geosites. Based on the research conducted (Pralong, 2005) cultural-historical significance includes such criteria:

1) Cultural and historical customs (depends on the symbolic relevance and heritage weight of the geosite for a community, this criterion is defined by the cultural and historical customs without taking into account physical vestiges or buildings);
2) Iconographic presentation (all historical pictures of the geosite are counted (painting, drawing, engraving, photography);
3) Historical and archaeological relevance (defined by the presence end relevance of historical, architectural, and (or) archaeological vestiges and buildings on the geosite);
4) Religious and metaphysical relevance (defined by the religious and metaphysical relevance related to the site, this criterion induces popular beliefs);
5) Art and cultural events (art and cultural events concerning the geosite are considered).

We decided to evaluate this category to reveal its meanings using the example of a geosite with the most pronounced criteria. This became the peak of Kalvária within the city of Banská Štiavnica.

The ecological category includes the following criteria (Andreychuk 2007, Trofimova 2012, Popescu, 2009):

1) Anthropogenic variation of the relief;
2) Anthropogenic garbage;
3) Graphic inscriptions on the surface of the relief form.

This is one of the categories where the criteria were evaluated in reverse order. For example, the complete absence of a characteristic was evaluated at 1 point, while a pronounced value was evaluated at 0 points. We decided to evaluate this category to reveal its meanings using the example of a geosite with the most pronounced criteria. This is what the Peklo cave in the landscape park of the palace within the village of Svätý Anton became.

The socio-economic category is based on the usable and workable characteristics of geosites (e.g. in a tourist and recreational context). The following criteria (Pralong, 2005) are distinguished here:

1) Accessibility (depends on the distance of the geosite from means of transportation and their relevance, in case of accessibility by cable car or train, the scale must be adapted);
2) Annual number of visitors in the region (the theoretical visitor potential of the geosite is taken into account by the annual number of visitors of the biggest resort in the region, the given score is identical for geosites of the same region);
3) Official level of protection (the official level of protection of the geosite, for this criterion, the economic exploitation is seen as inversely proportional to the limiting characteristic of the protection level);
4) Attraction (the absence of protection may be a tourist and economic disadvantage for geosite exploitation in terms of attraction of visitors from various origins).

We decided to evaluate this category to reveal its meanings using the example of a geosite with the most pronounced criteria. This is what the Parenica cave in the geothermal springs area within the village of Sklené Teplice has become.

Mountain landscapes are characterized by the streaming of different dangerous natural processes that are the reasons for accidents during excursions or campaigns. We assume that the following criteria are important from the standpoint of safety of stay and tourist activity of a person (Zhyrnov, 2015):

1) Availability of process (the presence of one or more processes that pose a danger to tourists);
2) Process intensity (rapidity and variability of the dynamics of the process for a certain unit of time);
3) Frequency of occurrence (number of repetitions of a process per unit of time);
4) The coverage area of the total area of the geosite (expressed as a percentage);
5) The degree of possible danger to human health and life (from mild symptoms to death).

This is also one of the categories where the criteria were rated in reverse order. The absence of a characteristic was rated at 1 point, while a pronounced value was rated at 0 points. We decided to evaluate this category to reveal its meanings using the example of a geosite with the most pronounced criteria. This is what the Kamenné more object within the village of Vyhne became. Various methodologies were considered for calculating the overall tourism score (Comănescu et al., 2025) but it was finally decided to use the formula proposed by Swiss geomorphologist Jean-Pierre Pralong (Pralong, 2005, p. 194) which is slightly modified by the authors of the article, since it includes ecological and safety values:

$$Vtour = \frac{Vsci + Vaes + Vcult + Veco + Vsec + Vsaf}{6}$$

Where *Vtour* – the general tourist assessment of the geosite; *Vsci* – the value of the geosite's scientific category; *Vaes* – the value of the geosite's aesthetic category; *Vcult* – the value of the geosite's cultural-historic category; *Veco* – the value of the geosite's ecological category; V*sec* – the value of the geosite's socio-economic category*; Vsaf* – assessment of geosite from the point of safety. No specific weighting factors are introduced because there is no objective reason to believe that one value is less important than another when we need to determine the overall tourism value of the geosite (Pralong, 2005).

The office stage of the study involved computer processing of the results: the saved geosite locations using the Mapy.cz application in the form of GPX files were transferred to a cartographic base and transformed into point shapefiles using the Conversion panel in the ArcGIS ArcMap 10.0 geographic information system. The attribute table of the data of the specified shapefile contained the calculated values of the overall tourist assessment of each geosite from each expert assessor. The final value of the tourist assessment of the geosite was recorded as the arithmetic mean of the 3 final assessments obtained by experts during the field stage of the study. The final product of the office stage was 3 maps that can be used by consumers for tourism purposes. The first is a map of the general tourist assessment of geosites of the Štiavnické vrchy territory at a scale of 1:25,000, the second is a map of the density of geosites at a scale of 1:50,000, superimposed on a map of the geomorphological zoning of the Štiavnické Vrchy, and the third is a map of the number of geosites at a scale of 1:50,000 per unit area. A fixed unit area was chosen for the first and third maps, which was ¼ square kilometer.

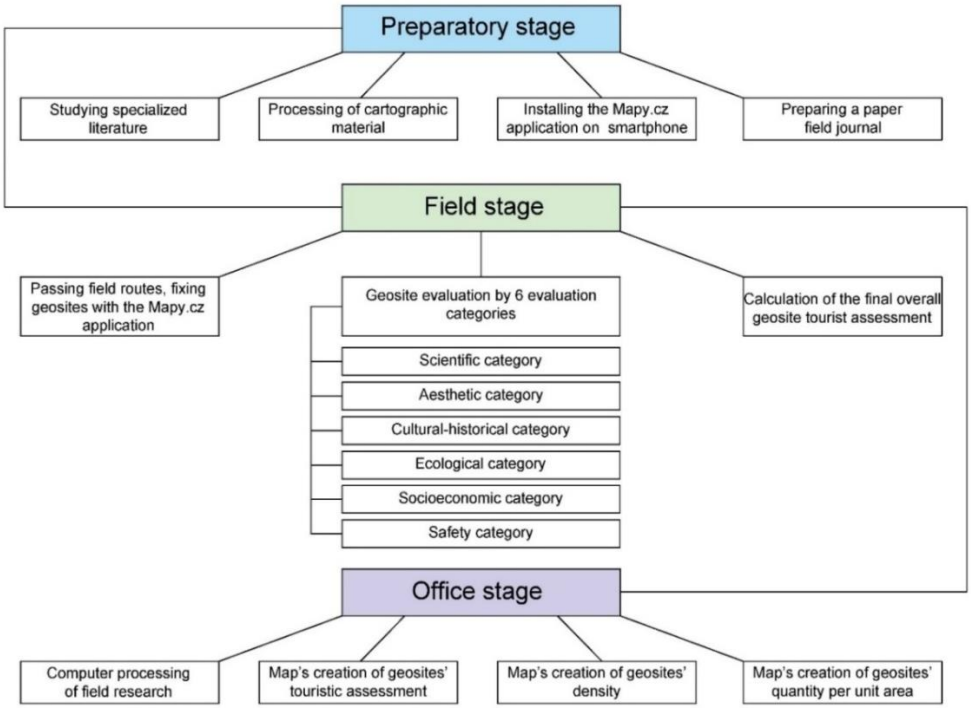

Figure 3. Methodology of current research (Source: Zhyrnov, 2024)

The average value of the tourist assessment of geosites was calculated for each square of the corresponding area in the first case, which fell within the given square, in the second case the number of geosites within the known area was calculated. The Zonal Statistics tool in the Spatial Analyst dashboard of ArcGIS ArcMap 10.0 software was used in both

cases. The final tourist assessment of the geosites of the Štiavnické vrchy area was divided into three categories: for sites with a low attractiveness value, a threshold with values up to 0.50 was recognized, sites of average attractiveness occupied a niche from 0.51 to 0.60, and highly attractive sites were recognized as those that received a rating of 0.61 and higher. It should be noted that the map of tourist assessment of geosites was supplemented with a diagram of the attractiveness values of each geosite, which was created in the Microsoft Excel program, and a table of tourist infrastructure that exists in the key settlements of the Štiavnické vrchy. Information on tourist infrastructure was taken from the tourist map "Štiavnické vrchy", 8th edition from VKÚ Harmanec, and is presented in a short tabular form. Additionally, a geosite density map was compiled using the Kernel density tool of the Spatial Analyst analytical panel, where areas of low, moderate, high, very high, and abundant geosite density were identified (Figure 4).

RESULTS

Let us evaluate some geosites based on the above methodology with certain most pronounced characteristics, which differ significantly from objects that do not have such characteristics and which significantly affect the final tourist assessment of geosites. The first examples of tourist assessment are the geosites "Glanzenberg", "Tanád" and "Kalvária vrch" (Figure 4). (Štrba et al., 2024; Palgutová et al., 2024)

Figure 4. Location (A) and appearance of mountain peaks (B – Glanzenberg; C – Tanád; D – Kalvária) in the area of Banská Štiavnica (Source: Zhyrnov, 2024)

Glanzenberg is a peak in the central part of Štiavnické vrchy, southeast of the Červená studňa saddle. The northern spurs of Banská Štiavnica rise along its steep south-eastern and south-western slopes. This mountain is crossed by rich ore veins Špitáler, Bieber, and Terézia. The gold and silver veins of Špitáler were mined by the Celts as early as the 3rd century BC – 2nd century AD, which represents the oldest open-pit mining in Štiavnické vrchy. The area was settled by miners at the turn of the 12th and 13th centuries, and a castle (Baňa) was built here in the 13th century to protect the town below the summit.

The settlement disappeared in the 17th century. The earthen rampart and fortress wall remain on the top, which was replanted with forest in the 20th century. The importance of fortification is also important according works of (Popescu, 2014). Archaeological research is being carried out here. Archaeological survey work has contributed significantly to understanding the history of the Baňa settlement and the castle on Glanzenberg (12^{th} -16^{th} centuries). The first excavations took place here in 1902 and 1903, and the next from 1931 to 1934. In 1956, Belo Polla of the Archaeological Institute of the Slovak Academy of Science examined the locality for two months. Among other things, he found a precious iron door with stone doorjambs.

Since 1981, the archaeological survey of Glanzenberg has been carried out by Jozef Labuda of the Slovak Mining Museum. He uncovered the remains of the castle, fortifications consisting of stone walls and "circumvallation" (defensive earthworks), residential houses, a water tank, the castle chapel, and various facilities for mining and ore processing-related activities. A panoramic view of the surroundings of Banská Štiavnica opens from the top after removing the forest (www4).

It becomes clear from the above that Glanzenberg Peak has a historical and archaeological past and present, and therefore the scientific characteristics of this peak have a pronounced background (Table 1). The arithmetic average of the scientific category for the Glanzenberg Peak is 0.75, which classifies it as a geosite with a high score for scientific significance.

Table 1. Criteria and scale of scoring used to assess the scientific category, example of the geosite "Glanzenberg" (Likhacheva & Timofeev, 2002, Pralong, 2005; Pereira et al., 2007)

Score / Criteria	0	0.25	0.5	0.75	1.0
Scientific 1: Paleogeographical value	–	low	moderate	High	very high
Scientific 2: Representativeness	–	low	moderate	High	very high
Scientific 3: Rareness	> 7	5 - 7	3 - 4	1 – 2	unique
Scientific 4: Integrity	destroyed	Strongly deteriorated	Moderately deteriorated	Weakly deteriorated	intact
Scientific 5: Diversity	1	2	3	4	≥ 5

Tanád (938.8 m above sea level) is the fourth-highest peak in Štiavnické vrchy. It is located approximately 2 km southwest of the center of Banská Štiavnica in the central part of the mountain range, on the eastern edge of the geomorphological region Hodrušská hornatina. The peak belongs to the protected landscape area «Štiavnické vrchy». From Tanád there are beautiful views of the nearby peaks – Paradajs (939 m), Cukmantel (855 m), Hadová (852 m), Kamenný závoz (768 m), Kanderka (862 m), Sitno (1,009 m), Vtáčnik (800 m) and Anderloch (810 m). Also visible are Pohronský Inovec, Vtáčnik, Malá Fatra, Kremnické vrchy, Nízke Tatry, Poľana, and Javorie in favorable weather conditions, as well as the south-eastward mountains of northern Hungary. The color scheme of the visible landscape is successfully complemented by the blue of mountain peaks, the green of deciduous forests, and the blue and white of the sky (www5).

Tanád is one of the mountain peaks with pronounced aesthetic characteristics and is one of the most visited places by travelers due to the wonderful views that open before the eyes of tourists (Table 2). The arithmetic average of the aesthetic category for the Tanád peak is 0.83, which classifies it as a geosite with a high score for aesthetic value.

Table 2. Criteria and scale of scoring used to assess the aesthetic category on the example of the geosite "Tanád" (Likhacheva & Timofeev, 2002; Kubalíková, 2013; Štrba et al., 2014)

Score / Criteria	0	0.25	0.5	0.75	1.0
Aesthetic 1: Uniqueness of landforms	non-unique	low	moderate	high	very high
Aesthetic 2: Uniqueness of landform surface appearance	non-unique	low severity	moderate severity	high severity	very high severity
Aesthetic 3: Architectonic and composition of landforms	–	low artistic	moderate artistic	highly artistic	ideal
Aesthetic 4: Visibility	–	limited	moderate	wide	exceptional
Aesthetic 5: Exoticism	not exotic	low	moderate	high	unique
Aesthetic 6: Expressiveness	not expressed	mild	moderate	pronounced	grandiose
Aesthetic 7: Attendant effects	–	barely noticeable	light background	tangible	contrasting
Aesthetic 8: Compatibility	incompatible	Slight compatibility	moderate compatibility	good compatibility	perfect compatibility
Aesthetic 9: Photogenicity	–	weak	moderate	good	ideal
Aesthetic 10: Emotional perception	indifference	minor interest	exciting	inspiring	amazing

The conical Kalvária vrch is an expressive dominant feature of the eastern part of Banská Štiavnica. In addition to the beautiful view of the peak itself, it is interesting for the whole complex of Baroque sacred monuments from 1744 to 1751. Kalvária tells the story of Jesus' last journey. It was built as a thoughtful interplay of architecture, sculpture, painting, and craft in unity with the natural environment. The Baroque architectural complex consists of 17 chapels, three churches, the Ecce Homo Chapel, and the Chapel of the Holy Sepulcher. The story of Jesus progresses on the left section of the complex up a natural steep slope to the Upper Church with its motif of the Crucifixion. Seven chapels depicting the seven sorrows of Our Lady line the return path on the right side of the site. Due to the efforts of local activists, Calvary was included in the list of the 100 most endangered monuments in the world at the beginning of 2007.

This was the start of a comprehensive monument restoration, the main phase of which ended in October 2018. At present, the restoration of the artistic elements – frescoes, altars, and sculptural decorations – continues (www1).

The Upper Church, the dominant feature of the Kalvária, was built in 1745. This is the culmination of the Stations of the Cross, dominated by life-sized statues of the crucified Christ and the thieves.

The main stage of the Kalvária's reconstruction was completed in October 2018, and less than a year later the first Holy Mass in decades was celebrated here (www1). From the above, it follows that Kalvária is a special geosite with strong cultural-historical significance (Table 3). The arithmetic average of the cultural-historical category for the Kalvária peak is 0.8, which classifies it as a geosite with a high score for cultural-historical significance.

Table 3. Criteria and scale of scoring used to assess the cultural-historical category on the example of the geosite "Kalvária vrch" (Pralong, 2005)

Score / Criteria	0	0.25	0.5	0.75	1.0
Cultural 1: Cultural and historical customs	without link	weakly linked	moderately linked	strongly linked	initiatory of custom(s)
Cultural 2: Iconographic presentation	never represented	represented 1-5	represented 6-20	represented 21-50	represented >50
Cultural 3: Historical and archaeological relevance	no vestige or building	weak relevance	medium relevance	high relevance	very high relevance
Cultural 4: Religious and metaphysical relevance	no relevance	weak relevance	medium relevance	high relevance	very high relevance
Cultural 5: Art and cultural events	never	–	occasionally	–	at least once a year

Table 4. Criteria and scale of scoring used to assess the ecological category on the example of the geosite "Cave Peklo" (Andreychuk, 2007; Trofimova 2012; Cocean, 2015)

Score / Criteria	0	0.5	1.0
Ecological 1: Anthropogenic changes in relief	high	Moderate	absence
Ecological 2: The presence of anthropogenic waste	high	Moderate	absence
Ecological 3: Application of graphic elements to the landforms' surface	high	Moderate	absence

The artificial cave "Peklo" is located in the park at Kaštieľ Svätý Anton (Figure 5). The cave has experienced significant changes made by man: the entrance to the cave has been refurbished, in the middle of the cave there is anthropogenic garbage and graphic elements on the surface of karst forms. The arithmetic mean value for the ecological category for "Peklo" is 0.5, which distinguishes this geosite from other anthropogenically undisturbed landforms (Table 4).

The most pronounced socio-economic category is characteristic of the cave stream bath Parenica, which is located in the resort village of Sklené Teplice in the north of Štiavnické vrchy (Figure 6).

Figure 5. Location (A) and appearance of artificial cave «Peklo» (B) (Source: Authors fieldwork, 2024)

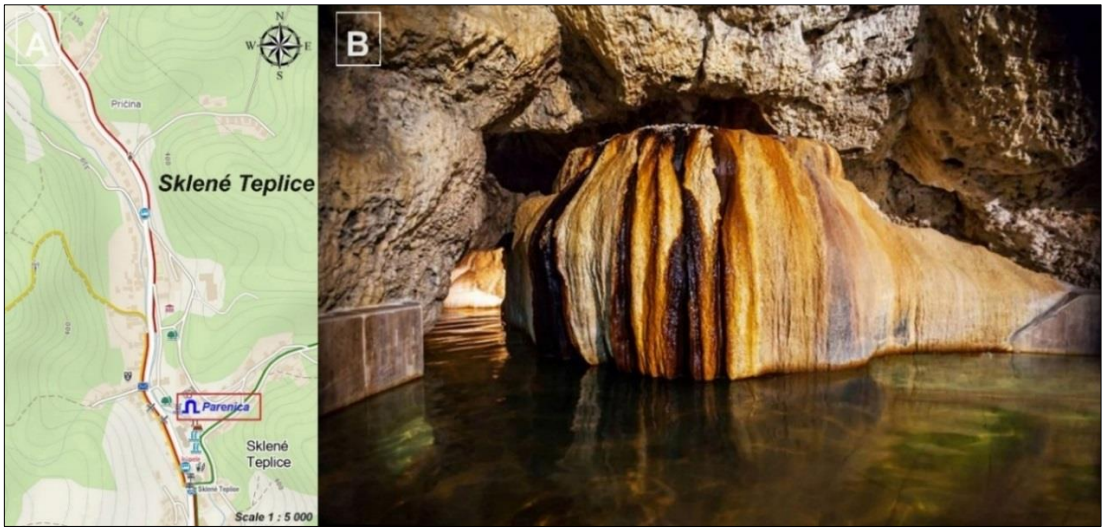

Figure 6. Location (A) and appearance (B) of cave stream bath «Parenica» in the area of Sklené Teplice (Source: Authors fieldwork, 2024)

Parenica is a unique steam bath in a naturally created cave, which is one of the unique SPA phenomena in Europe. The water in the cave comes directly from the thermal spring, it is only slightly cooled to preserve the rare concentration and strength of the mineral composition, and its temperature (42 ° C) is acceptable for the human body. The natural water flowing over the surface of the cave is not only rich in calcium and magnesium but also other rare minerals, which makes staying there especially suitable for tourists with musculoskeletal diseases. This SPA complex is widely known outside Central Europe. Tourists from many countries of Western and Central-Eastern Europe come here for wellness purposes, which makes this geosite both one of the most visited places in Štiavnické vrchy and an attractive tourist and recreational resource. The cave is located in an accessible location – next to the local road 2498 "Hliník nad Hronom – Sklené Teplice – Podhorie", it can be easily reached by personal or municipal transport (Chovanová & Nižňanská, 2010).

Taking into account the above factors, it follows that the Parenica cave is a geosite with relatively pronounced socio-economic characteristics (Table 5). The arithmetic average of the socio-economic category for Parenica cave is 0.5, which classifies it as a geosite with an average (above standard) score for socio-economic importance.

Table 5. Criteria and scale of scoring used to assess the socio-economic category on the example of the geosite "Cave Parenica" (Source: Pralong, 2005)

Criteria \ Score	0	0.25	0.5	0.75	1.0
Socio-economic 1: Accessibility	≥ 1 km of track	< 1 km of track	by a local road	by a road of regional importance	by a road of national importance
Socio-economic 2: Annual number of visitors in the region	< 10 000	10 000 – 100 000	0.1 – 0.5 million	0.5 – 1 million	> 1 million
Socio-economic 3: Official level of protection	complete	limiting	–	not limiting	no protection
Socio-economic 4: Attraction	–	local	regional	national	international

At the foot of the Kamenná mountain, towering above the village of Vyhne, there is a unique creation of nature – the Kamenné more. This site, formed by countless large or smaller rhyolite boulders of a reddish color, is the largest and most important of its kind in Slovakia. This is the largest stone sea in the volcanic part of the Carpathians and one of the oldest protected areas in Slovakia, valuable primarily for its geological features. The sight of this Kamenné more, surrounded by forest, inspires respect and leaves a strong impression. The Kamenné more at Vyhne owes its origin to the process of erosion, as well as an earthquake that caused a massive rock collapse thousands of years ago. The Kamenné more can be reached along the Andrej Kmeť educational trail, the starting point of which is the village of Vyhne (Figure 7) (www2).

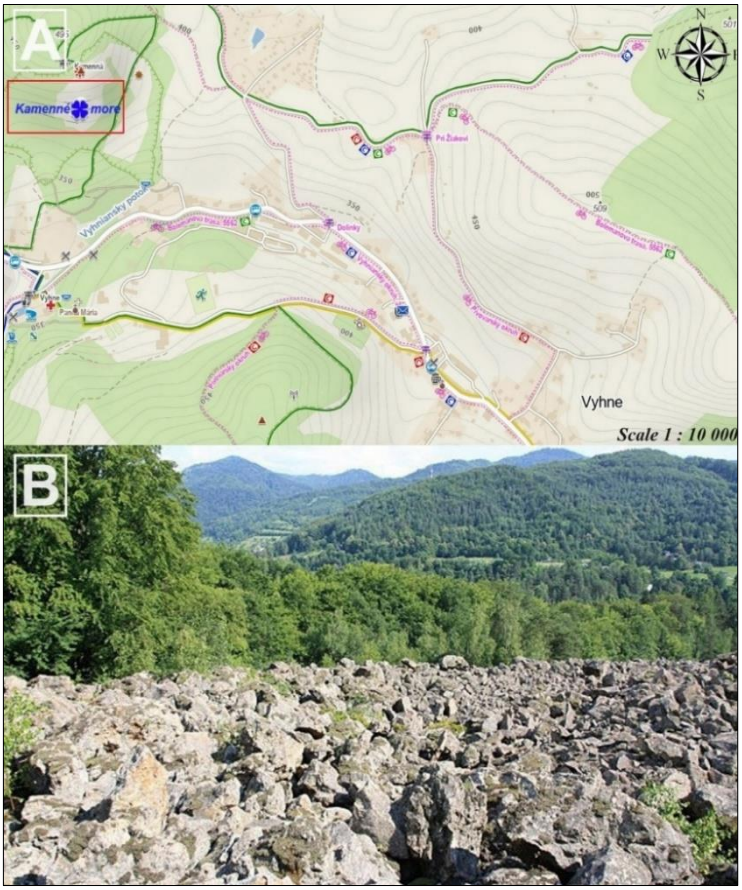

Figure 7. Location (A) and appearance (B) of the stone sea in the area of Vyhne (Source: Zhyrnov, 2024, village Vyhne)

However, this geosite is notable not only for its beauty and unusualness. The Kamenné more is considered a rather dangerous place for tourists to stay for several reasons. Firstly, when making your way along the uneven and sharp boulders of the Kamenné more, you can easily trip and fall on the stones, which will result in injury. Secondly, in the summer heat, the Kamenné more gets quite hot, and staying in such a place can easily cause heat stroke to the body, so it is better to visit this geosite in spring or autumn when this risk is excluded. So, we have at least one circumstance that makes visiting this place relatively dangerous and requires the tourist to be attentive and careful (Table 6). The arithmetic average of the safety category for the Kamenné more is only 0.2, which classifies it as a geosite with a low score for the safety of tourists, therefore this landform is dangerous to visit.

Table 6. Criteria and scale of scoring used to assess the safety category on the example of the geosite "Kamenné more" (Zhyrnov, 2015)

Score / Criteria	0	0.5	1.0
Availability of process	≥ 2	1	absence
Process intensity	high	moderate	absence
Frequency of occurrence per year	≥ 3	1-2	absence
The coverage area of the total area of the landform	≥ 20 %	15-20 %	absence
The degree of possible danger to human health and life	severe	mild to moderate	absence

All 153 geosites were assessed according to the above-described assessment categories within the Štiavnické vrchy geomorphological region. On the corresponding map (Figure 8) we can see the spatial distribution of geosites and their overall tourist assessment. The cartographic basis is represented by a hydrographic network, a network of roads, railways, bicycle routes, and hiking trails. The marked settlements show the existing tourist infrastructure. Some of the most interesting geosites in the Štiavnické vrchy are attached to the map as examples (Al Mohaya & Elassal, 2023).

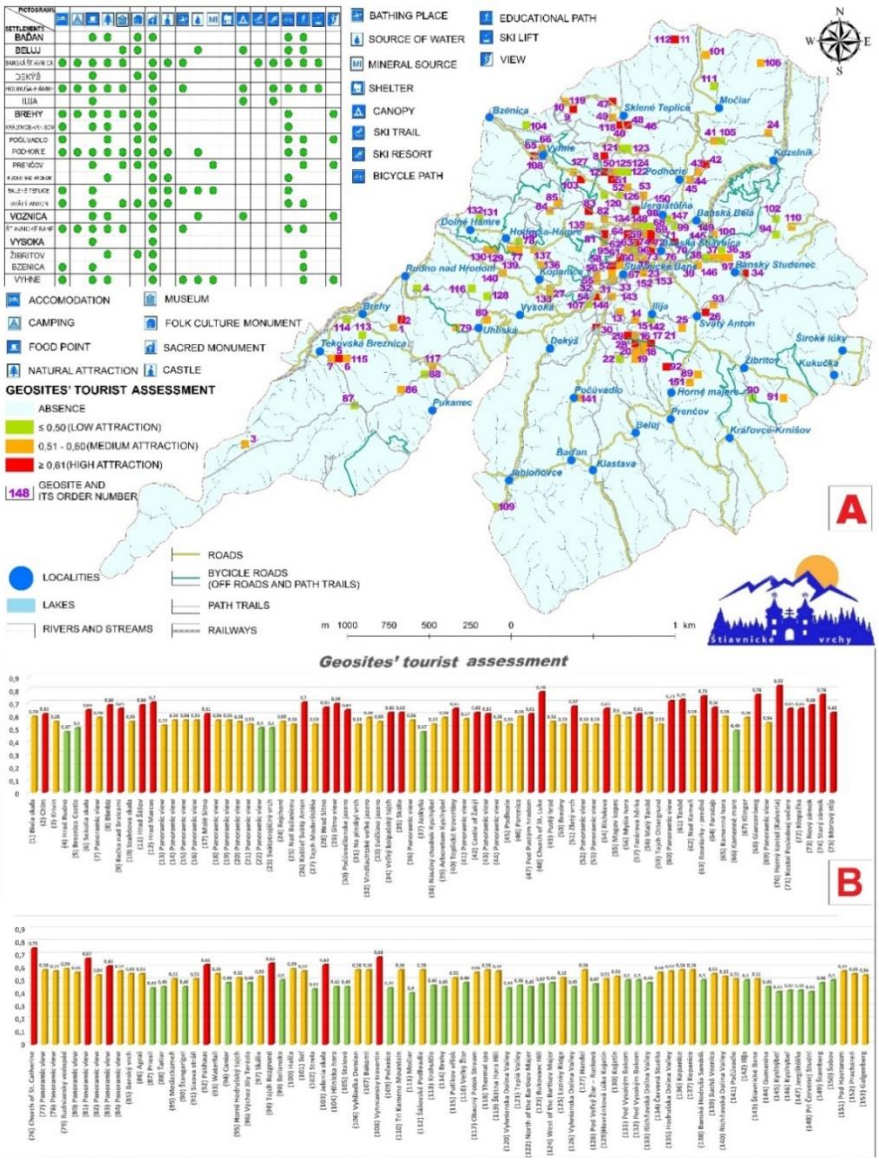

Figure 8 (A-B). Map of tourist assessment of geosites on the territory of Štiavnické vrchy, (A) diagram of geosites' tourist assessment, (B)

Figure 8(C). Photos of geosites according to their location (C) on the map (C) (Source: Zhyrnov, 2024)

The density map of geosites shows that the largest number of them are located within a radius of 20 km from the city of Banská Štiavnica in the central part of the Štiavnické vrchy, mainly within the geomorphological regions of Štiavnická brázda and Hodrušská hornatina. The geomorphological region of Sitno also stands out for its high density of geosites. It should also be noted that the northern, eastern, southern, and southwestern parts of the Štiavnické vrchy do not have any geosites and remain unattractive and difficult to access territories for tourists (Figure 9).

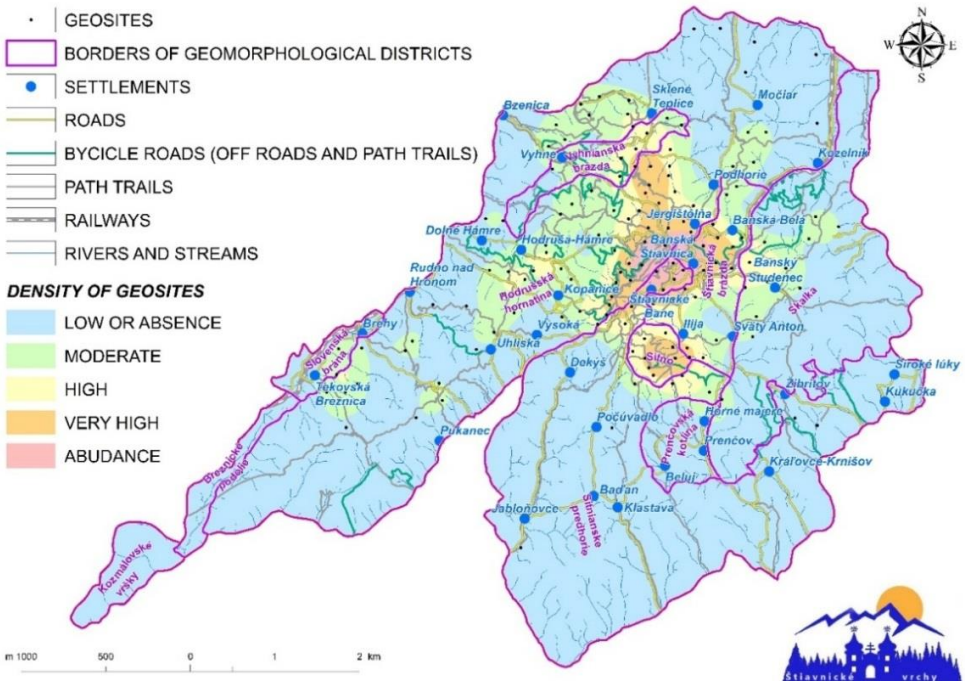

Figure 9. Map of geosites' density on the territory of Štiavnické vrchy (Source: Zhyrnov, 2024)

On the map of the number assessment of geosites within the areas of ¼ square kilometer, one can also see the pattern that the largest number of geosites are located in the vicinity of the city of Banská Štiavnica and the area of the highest peak Sitno of the Štiavnické vrchy (Figure 10) (Diniz & de Araújo, 2022).

DISCUSSION

The tourist assessment of geosites in the current study consisted of six assessment values: scientific, aesthetic, cultural-historical, ecological, socio-economic, and safety. However, this may not be sufficient for a complete and objective tourist assessment. In our opinion, it is worth considering the morphometric value for tourist assessment of geosites, since morphometric indexes define visibility, attraction, variety, and passability of the territory and constitute the microclimatic conditions of locality (Zhyrnov, 2015; Popescu, 2006).

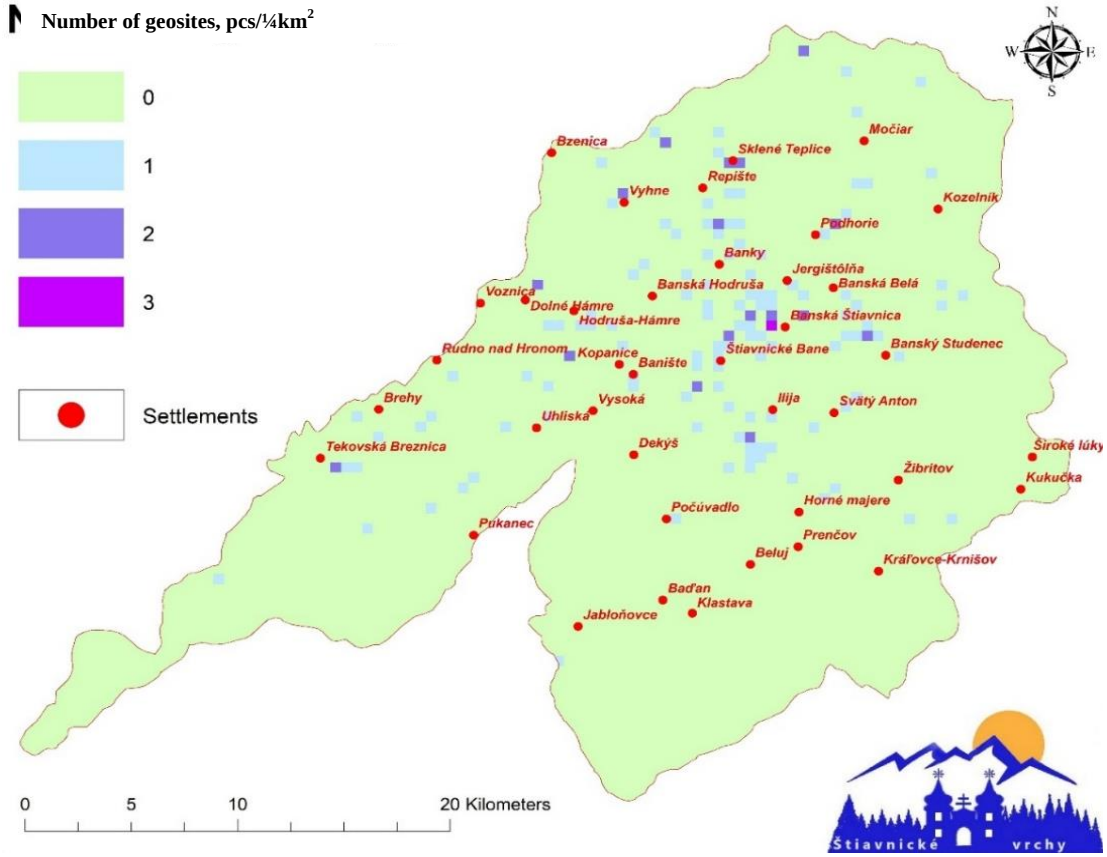

Figure 10. Map of geosites' quantity (pcs/¼km^2) on the territory of Štiavnické vrchy (Source: Zhyrnov, 2024)

According to the views now dominant presentation (Bredikhin, 2004) such morphometrical indexes play a key role in tourist assessment: absolute altitude of the surface, gradient of slopes, slope exposure, vertical and horizontal dissection of relief (Table 7) (Zhang et al., 2024; Oppizzi et al., 2023; Mackenzie, 2024; Olteanu et al., 2024; Cirillo et al., 2024; Carrión-Mero et al., 2025; Petrović et al., 2025).

Table 7. Characteristic of main morphometrical indexes for geosite assessment (Source: Bredikhin, 2004; Zhyrnov, 2015)

Morphometric indexes	Influence on tourist activity
Absolute altitude	Defines visibility and attraction of the territory, the existence of a visible variety of landscapes and high-altitude zones. Informative, emotional and psychological effects are closely connected with visibility.
Horizontal dissection	Defines the variety and passability of the territory and, the transportation possibility for vacationers and service personnel. Defines the creation of the infrastructure connected with tourism.
Vertical dissection	Defines a variety of a landscapes, the review of the panorama, esthetic satisfaction from the relief, degree of passability, and availability of the territory.
Gradient of slope	Defines the prime cost of tourism engineering constructions and the passability of the territory. The quantity of solar energy and illumination of the relief depends on the gradient of the slopes. These facts must be taken into consideration by recreational organisations.
Exposure of slope	Defines frequency of the relief with solar energy. The southern exposition slopes are the most comfortable for tourist activity in temperate climatic zones of the northern hemisphere. Completeness of a range of expositions allows to choose of areas of different functions for tourist activity for uneven-aged people.

Morphometric values of relief determine the complexity category of a tourist route and influence the accessibility of the relief for tourist activities. For example, low accessibility of the relief gives rise to certain forms of tourism (mountaineering, rock climbing), while high accessibility of the relief opens up opportunities for various types of recreational tourism (tourist walks, hiking) (Ovreiu et al., 2018).

It should be noted that morphometric indicators of relief affect not only the visibility, attractiveness, diversity and passability of the territory, but also have important engineering significance and can influence the location of tourist infrastructure, buildings and structures. The engineering and construction assessment of the territory depends on the morphometric indicators of the relief. As a rule, with an increase in morphometric indices, the complexity of construction development of the area increases, which requires special architectural and design solutions, as well as engineering protection of the territory from dangerous geological and geomorphological processes (Gavrilă, 2012).

We propose to realise the zoning of nature systems according to morphometrical criteria, considering the relief as a recreational resource for hiking and trekking (Table 8) (Bredikhin, 2004; Zhyrnov, 2015).

Table 8. Zoning of nature systems according to morphometrical criteria for tourism adaptation (Bredikhin, 2004; Zhyrnov, 2015)

Absolute altitude (m)		The gradient of slopes (°)		Vertical dissection (m)		Horizontal dissection (km)	Score
hiking	trekking	hiking	trekking	hiking	trekking		
>1500	0-500	>45; 12-45	0-3; 3-6	>800	<300	>2.5	0.25
1000-1500	500-1000	6-12	6-12	600-800	300-600	2.5-1.2	0.5
500-1000	1000-1500	3-6	12-45	300-600	600-800	1.2-0.8	0.75
0-500	>1500	0-3	>45	<300	>800	<0.8	1.0

However, it should be noted that the tourist appeal of mountainous areas depends not only on the morphometric indicators of the relief. Morphogenetic types of relief and its morphosculpture play an important role, determining the diversity of external forms and the aesthetics of the relief. Therefore, morphometric analysis of the relief must be carried out in conjunction with related types of geomorphological surveys, since it is a comprehensive approach that will help to adequately divide the territory into zones according to its tourist potential (Oprea-Gancevici & Cheia, 2012).

CONCLUSION

The aim of the article was limited to the tourist assessment of geosites of the Štiavnické vrchy mountain range according to certain assessment values, in order to ultimately create an assessment map of the attractiveness of geosites and propose measures to improve the tourist potential of areas characterized by low attractiveness or absence of geosites. (UNESCO, 2023a; UNESCO, 2023b; Pramuková et al., 2025; Băndoi et al., 2020; Vandelli et al., 2024). As you can see, Štiavnické vrchy has significant tourist diversity. Every tourist can find something that will be interesting or useful for him. However, tourism resources in Štiavnické vrchy are unevenly distributed and there are sites on their territory that today have low tourist attractiveness or even its complete absence. Having assessed the geosites based on the methods of leading geomorphologists, we can draw certain conclusions on how to improve the unattractive areas of the Štiavnické vrchy.

So, the northern, eastern, southern, and south-western directions of Štiavnické vrchy require measures to organize artificial attractive objects to increase the overall tourist attractiveness of such sites. Considering that the main natural wealth of sites with low tourist assessment is forests, a good idea for the designated sites is to create forestry arboretums modeled after Arborétum Kysihýbeľ, which is located on the eastern outskirts of Banská Štiavnica (www3).

In such arboretums, it is possible to grow rare forest species, introduce tree species of different climates, carry out landscape design of the territory, create educational tourist trails, etc. Another possible way to increase tourist attractiveness is to create a variety of museums based on the historical, cultural, and natural conditions of such territories (Kim et al., 2020; Popescu & Ionescu, 2016). Another possible direction is gastronomic tourism, which involves the creation of cafes and restaurants serving Slovak and foreign cuisine, as well as local delicacies (Cunha, 2018).

Forest areas in the southern part of Štiavnicé vrchy alternate with small intermountain valleys, within which horseback riding can be organized (Helgadóttir & Sigurðardóttir, 2008). The southern and southwestern territories of Štiavnické vrchy are represented by rural settlements with a developed agricultural production complex, which is optimal for the creation of a tourism industry sector focused on the use of natural, cultural, historical and other resources of the countryside and its features to create a comprehensive tourism product. Rural tourism in designated areas may include services such as accommodation in cozy private estates, custom-made meals from organic products, learning about the history of the region, mushroom and berry picking trips, and participation in folk rituals (Demkova et al., 2022).

Further development of tourism in these territories is only possible with the clearing, leveling, and arrangement of tourist trails, which are currently in unsatisfactory condition. When implementing such activities, possible areas would be walks in the forest, organized recreation near water bodies and in the forest, skiing and cycling tourism, sporting events (including cross-country, and triathlon), forest and sports orienteering, arrangement of ecological trails, familiarization with natural and historical and cultural heritage in forests (Font & Tribe, 2000) familiarization and observation of representatives of the animal and plant world in natural conditions (Dybsand, 2021). However, such events are economically and labor-intensive and require full support from the state or economic programs for the development of tourism of various funds of the European Union. Nevertheless, in the long term, they are justified, since they will ensure sustainable environmental development and economic prosperity of the region (Băndoi et al., 2020).

One can consider the morphometric assessment category as an addition to the existing methodology for the tourist assessment of geosites. It determines the visibility and attractiveness of the territory, the presence of visible diversity of the landscape, the permeability of the territory, the insolation of the relief, and the construction of tourist infrastructure.

The described methodology allowed for a comprehensive assessment of the tourist attractiveness of geosites from the perspective of scientific, aesthetic, cultural-historical, socio-economic, and environmental values, as well as safety criteria. As a result, 153 geosites in the Štiavnické vrchy mountain range were assessed and a map of the tourist attractiveness of geosites was compiled, highlighting areas with low, medium and high attractiveness.

Measures to increase the tourist potential by creating artificial attractions are proposed for areas of Štiavnické vrchy, which are characterized by the presence of low-attractive geosites or their absence. The tourist assessment of geosites is

not limited to the estimated values given, so the authors of the article are open to scientific discussion on possible assessment categories for attractions, which will ultimately improve the assessment of geotourism zoning.

All interested specialists are invited to participate in this discussion.

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