

IDENTIFYING OUTCROPS FOR GEOLOGICAL HIKING MAPS

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Abstract

Geotourism has been a fast-growing sector of tourism in the past decades. It focuses on geologic and scenic values of a location (geosite), so these can be preserved and popularized easier. The objects of geotourism are the outcrops: these are the main tourist destinations and carry the visible geological information. Thus, the most important task when compiling such a map is to identify the most valuable geosites. The first step of a geosite assessment is to list all the possible geolocations by collecting data from geological and topographic maps, Picasa photos and key section list. Subsequently the list is filtered with GIS and classifying methods. The goal of our project is to find suitable geosites for the first geological hiking map of an area of the Bakony–Balaton UNESCO Global Geopark, that is the main outcome of this work. The result also helps nature conservation by giving attention to remarkable locations.

Keywords: tourist map, hiking map, geology, GIS, filtering, geopark, geotourism, Hungary

WHAT IS GEOTOURISM? WHY IS IT IMPORTANT?

As a relatively modern branch of tourism, geotourism has been enjoying more and more popularity nowadays. The positive effects of the global information revolution in the past decades influenced people with high need of knowledge, globetrotting and love of nature who started to unearth the treasures of our planet. Thomas Hose (1995) made the first big step in order to deepen the concept of geotourism, and after two decades of formation and refinement we generally use the definition of Newsome & Dowling (2010). According to this, geotourism is a wing of tourism that focuses on geologic and landscape values. It subserves the popularization of these targets (geosites), helps to preserve geodiversity and the apprehension of different earth sciences.

Some features unambiguously discern geotourism from tourism in general. On the one hand it carries information through the presentation of geologic heritage, that generates satisfaction in visitors and tourists. On the other hand, these sites are informative for inhabitants too, as the scientific knowledge becomes the part of their identity. But it is also important to take care about non-scientific attractive factors too because everybody can visit these destinations: experts on geology and guests who are not conscious and aware of earth science (Dowling, 2011; Grant, 2010).

Geotourism also means more sensitivity and interest towards natural and cultural values. Beside enjoying free time environmentally sound attitude is also essential as a geotourists concentrate on broadening their minds and nature preserving too. Geotourism also stimulates local communities to cooperate to make tourism destinations more attractive. It also has economic role too: by building infrastructure workplace establishment and monetary benefit is also mentionable (Dowling, 2011).

The organized institutions of geotourism are geoparks (*Figure 1*). The protection of inanimate natural formations had not found international support until the past decades. By the inception of the European Geoparks Network (EGN) and the Global Geoparks Network (GGN) among intense popularization, environment protective viewpoints were taken into consideration. We need to emphasize the openness of geoparks: these are not closed nature conservation areas, but open

institutes for everyone with an aim to bring people nearer to geoheritage. Beside promoting geologic features, geoparks also pay attention to cultural, historical, ecologic and educational values (Bakony–Balaton Geopark, 2012).

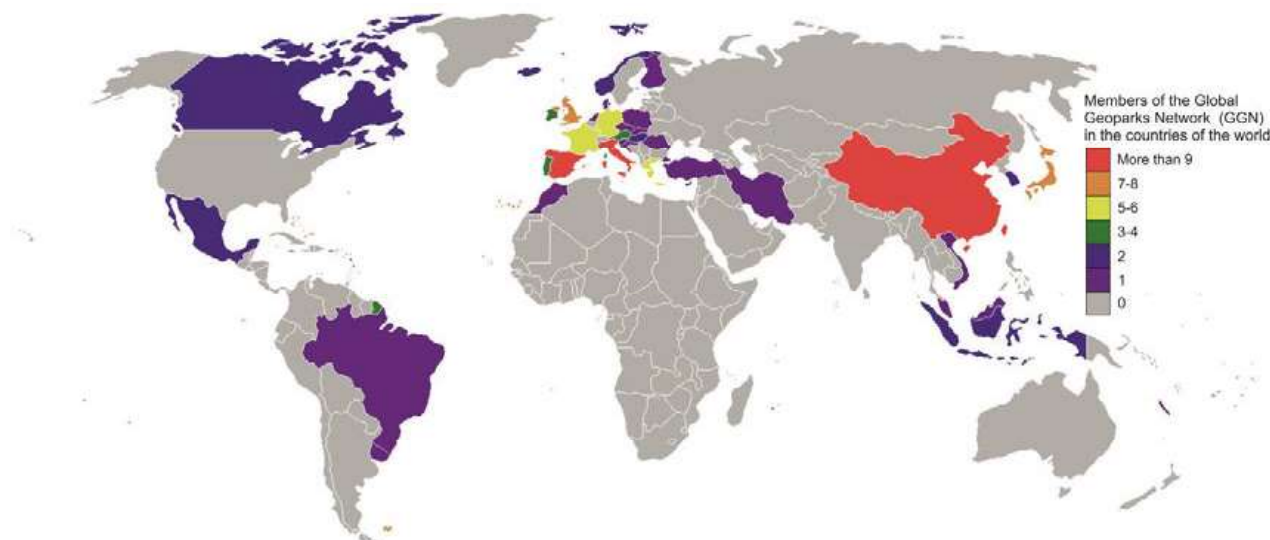


Figure 1. Global Geoparks in the world, 2018.

Earth scientific values are visible and represented by geosites within geoparks. Geosites are the most interesting, exciting and spectacular inanimate formations of the environment. These formations can be a great variety of natural objects: cliffs, caves, outcrops or even the landscape. With their examination we can investigate a specific period of the chronology of the Earth. In other studies, we used different scientific factors (e.g. the rarity of a specific geological formation or the geoscientific publicity), but within this work we mostly try to put emphasis on the infrastructural and GIS analysable factors of appointing a geological outcrop to be a presented geosite.

THE CONNECTION BETWEEN GEOTOURISM AND CARTOGRAPHY: GEOTOURIST MAPS

Traditionally the origin of tourist and geological maps roots back to topographic maps. Each map contains deduced cartographic information: while tourist maps are designed for field use and keep most of the original information, geological maps contain specialized information that are not relevant for orientating – they were mainly designed for office use or wall-maps. Slowly it was recognized that people with geological interest need maps that help them to identify geological/geomorphological formations and lead them on the field. The accumulated knowledge and the possibilities of geotourist maps were summed up in several studies (e.g. Albert, 2004; Martin, 2010; Regolini-Bissing, 2010). The work of Albert (2004) involved large and medium-scale maps in Hungary. However, the next publication, the first geological hiking map of Hungary was only published in 2018 depicting the eastern part of the Bakony–Balaton Geopark, Hungary (Albert, Pál & Schwarcz, 2018). The aspects, features and attributes of identifying outcrops and making geotourist maps are presented throughout the example of this map.

As we can see the properties of traditional tourist maps and geological-geomorphological maps are merged together in a geotourist map. The legend of these maps is slightly complicated than the legend of geological maps: among the dominant role of geological features (e.g. formations denoted by different colours, normal and reverse faults) it contains signed hiking trails, remarkable gazebos and sights as well as information that help tourists arriving by either car or bicycle. We can state that approximately half of the legend elements comes from geothematic maps while the other half is derived from topographic maps, since relief, road and water network, geographical names have essential role in orientation (Albert, 2004).

Both large and medium scale maps are suitable for geotourism purpose. While large scale maps (1:5000 – 1:50 000) are mainly made to assist tourists on the field containing nearly accurately presenting the main characteristics of geosites, medium scale maps (1:50 000 – 1:500 000) are mainly used for overviewing an area: they contain just the most important tourist attractions and the main traffic information after generalization. By the reason of this difference, there is also a contrast in the map making process. As medium scale maps do not contain detailed information, it usually can be deduced by existing cartographic products, while the data presented on large scale geological hiking maps must be checked on field to give first-hand and fresh facts about the area. The selection of geosites has a high priority, as they are the most important elements of this type of map as they carry the visible and visitable geological information on the surface (Reynard et al., 2009). In this study the geometrical aspects of assessing geosites is discussed in detail.

GET TO KNOW THE AREA!

One of the most famous tourist destinations in Central Europe is the surroundings of Lake Balaton, the area of the Bakony–Balaton UNESCO Global Geopark (*Figure 2*). The shore of the lake is bordered by reed, but somewhere only after a few hundred metres starts the mountainous area. The northern coast is a part of the Transdanubian Mountains and is well-known for its wines, spas and exciting geological formations. Its climate next to the shore has Mediterranean features (where grape is grown), while in higher latitudes is mainly temperately cool and wet. It has no great rivers, but the climate in deep valleys is cool during hot summers too thanks to the small streams called “séd”. Balaton Uplands National Park and Bakony–Balaton UNESCO Global Geopark takes care of the natural, touristic and cultural values of the area (Dövényi, 2012; Futó, 2013). Rocks have a long history here that dates back to ancient times when life was only present in oceans. The area was transformed by volcanoes, deep and shallow seas, deserts, lagoons in the following millenary of years. These transformations have been generated by tectonic movements that produced fierce earthquakes that have fractured, folded plates into mountains. Because of this activity such rocks as in the Alps can be found here (e.g. the Main Dolomite/Hauptdolomite). This work studies the eastern part of Balaton Uplands (Albert, Pál & Schwarcz, 2018).

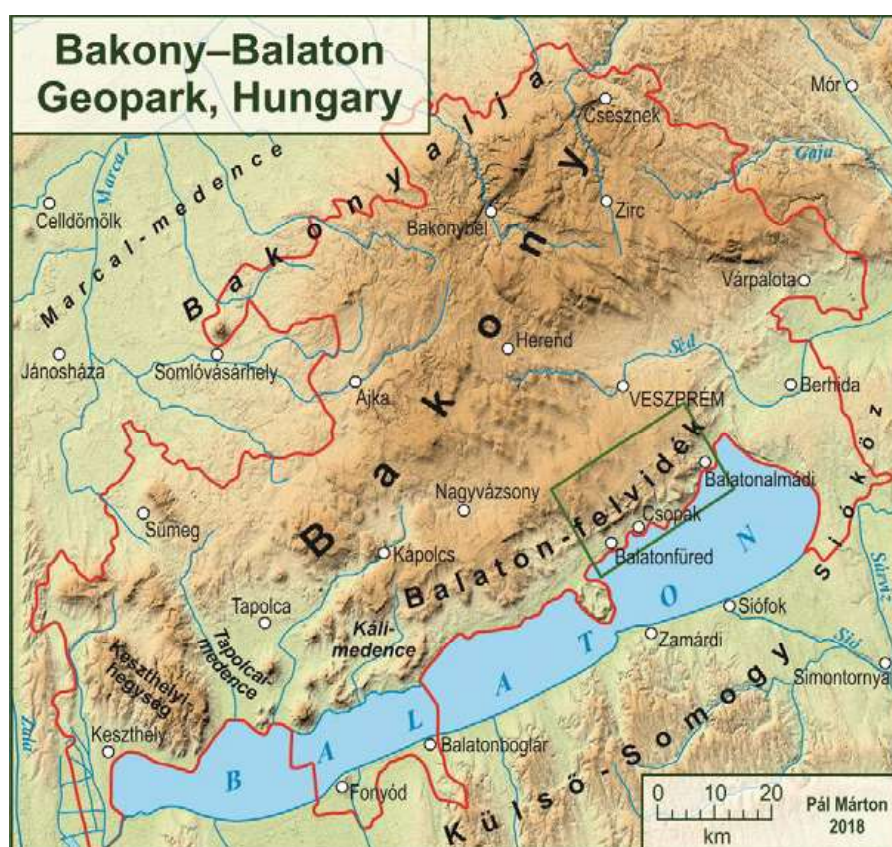


Figure 2. The extent of the Bakony–Balaton Geopark (red border) and the examined area (green border)

OUTLINES OF THE DATABASE AND DATA GATHERING

At the beginning of the project our aim was clear: carry out a geosite assessment to filter gathered potential geosites in order to get the most popular and valuable geosites of the area. The result of this filtering was going to be presented on the published map. To conduct an assessment, we had to designate geosite nominees. We searched for maps that may contain relevant topographic and geological information. We chose topographic (1:25 000 military maps in Gauss-Krüger system, 1:10 000 EOTR-Uniform National Mapping System sheets) and geological maps (1:20 000 Engineering geological map series of the surroundings of Lake Balaton, 1:50 000 Geological map of the Balaton Highland). As these maps are at least 20 years old, we needed current information to get more approximate results. First, we filtered the database by the shape of built-up areas (that have extended in the past decades) and mining sites database (geotourism activity is prohibited in these areas). To specify the gathered data, we used the key section list of the Hungarian Geological Survey (MBFSZ) and Google photos. The map work and database-shape building were conducted in the freeware QGIS 2.18 software.

Topographic maps

The military topographic maps in the second half of the 20th century made by the Hungarian Army are parts of the international Gauss-Krüger system, following the model of the Soviet Union. The used 1:25 000 map sheets were edited between 1953-1959 (“new survey”) and were renewed in the 1980s. The situation of civilian topography was slightly complicated. As there were no larger scale maps than 1:25 000 for non-military purposes, civilian mapping made 4098 sheets of 1:10 000 scale after 1957 (“maps for people’s economic purpose”). Because of Soviet pressure the projection and the sheeting system had to be changed to divide military and civilian mapping. As a result of this, the production of Uniform National Mapping System (EOTR) was ordered. Its name refers to the procession of cadastral and topographic maps too. It has a unique projection (EOV – Uniform National Projection) that is a conformal cylindrical projection in transversal position. The mapping work was completed in 2000. Both military and civilian topographic maps form a system of different scales (Zentai, 2015).

Considering the designated area, we searched for the corresponding map sheets of the 10k and 25k maps. Some of them were already scanned and georeferenced, but there were remaining sheets that needed this preparatory work. After that, all elements with the possibility of geosite features were searched for in the official map keys. Then all collected and georeferenced map sheets were examined, and all items presented on *Figure 3.* were inserted into the QGIS database as a point feature.

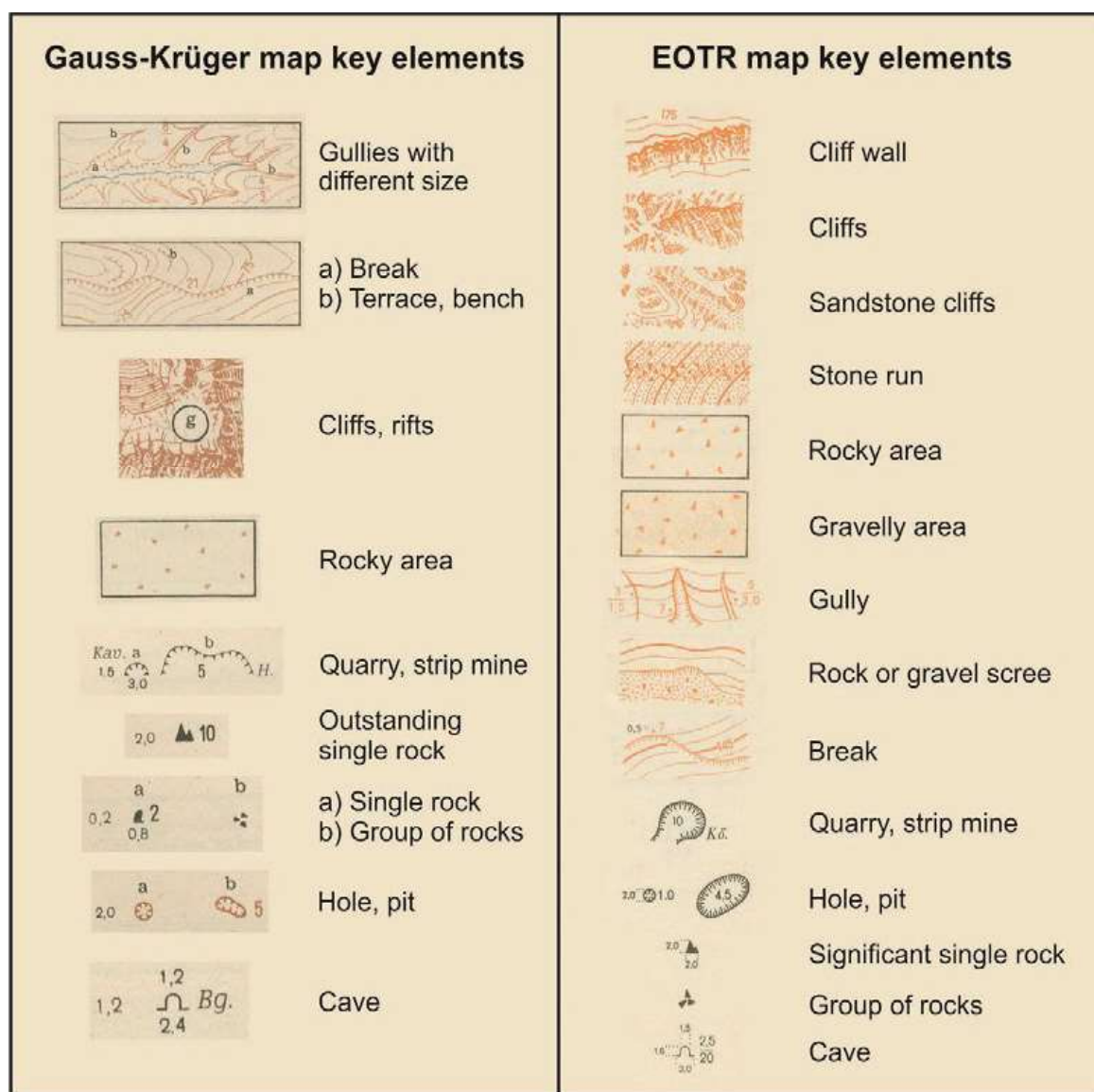


Figure 3. The searched map key elements on the chosen sheets – each of them was recorded as a point feature (MNTI, 1964; MÉM OFTH 1977)

Geological maps

The Engineering geological map series of the surroundings of Lake Balaton (1:20 000, 1986, *Figure 4*) can be examined in the library of the Hungarian Geological Survey. As a large-scaled geological map, it contains lots of outcrops (either clastic or intact), boreholes, mines, quarries and explorational pits. The recording of this data was similar to the topographic method: each feature had its own attribute, and to make further work easier, outcrops were divided into three size groups according to their map size (<5 cm; 5-10 cm, 15 cm<). This grouping had its importance during the filtering.



Figure 5. An excerpt of the engineering geological map. Larger (small polygons) and small (X signs) outcrops, research pits (polygons with dashed borders) and mines are visible

The Geological map of the Balaton Highland (1:50 000) was available to be georeferenced. As a consequence of its large scale it does not depict outcrops. By merging and working together the geological theme of both maps and other information sources (e.g. MBFSZ maps online), we were able to make a tourist-friendly simplified thematic legend. Its need has two reasons: tourists does not need the full amount of scientific information and all formations represented on the map would have extremely hardened the legibility of the map. After this standardization, the polygons of features were digitized in QGIS, so we got a geological base map for the recorded point features.



Figure 6. An excerpt of the topologically checked geological thematic polygons

BRIEFLY ABOUT GEOSITE ASSESSING

To make a concept about the weight of the correct identification and representation of outcrops, we need to define what geotouristic potential is. As geotourism, it is also a relatively modern term. According to the international definition, touristic potential sums up the value of each remarkable destinations considering supply, current use and possibilities of future development and successes (Lai & Graefe, 2000; Melián-González & Garcia-Falcón, 2003). This definition is easily applicable on geosites too.

There is a qualitative and a quantitative way to estimate the geotouristic potential of a geosite. In order to get more realistic and subjective results, we used quantitative methods called Geosite Assessment Model (GAM) and Modified Geosite Assessment Model (M-GAM). These models are built up of two main groups: one group of indicators shows the educational and scientific values of a geosite, while the other group is responsible for the infrastructural points. M-GAM is derived from GAM by taking into consideration the opinion of geotourists about the GAM evaluation indicators as a factor. By evaluating every indicator (e.g. Rarity of formation, Current condition of geosite, Distance of main traffic routes...) every geosite gets its own point that refers to its scientific and infrastructural development and further possibilities (Vujičić et al., 2011; Tomić & Božić, 2014).

The scoring of indicators has different methods. Scientific ones were assessed by the help of experts, ones considering the physical condition of geosites by personal experience during field trips, while others (mainly ones connected to infrastructure) could be solved by GIS. Among the complete map drawing process this work phase and the filtering were carried out by the help of different GIS functions.

THE PRECISION ROLE OF GIS IN GEOSITE ASSESSMENT

Filtering

At the point when we finish gathering point feature data from topographic and geological maps we come across the fact that probably thousands of different points form our database. This huge amount of "geosites" is not suitable for being presented on a map. As data sources are at least 30 years old, we need to make constraints that will be the phases of filtering and redefining our geosite set.

First, we need to realize that built-up areas have extremely extended in the past decades, especially in recreation areas. We chose the database of OpenStreetMap to filter the set of points by the current extent of settlements and industrial areas. After making a spatial query we see that the number of elements decreased. There is an also essential filtering phase: in Hungary mining areas with a permission cannot be visited or passed through even if there is no activity. To filter out sites falling into these areas, we can download the continuously updated database of mining areas of Hungary in KMZ format. As it can be easily converted to shape, a query like the preceding can be carried out.

In this state we probably have nearly the same number of records in the database (*Figure 6*). But it is an important outcome that we do not count with prohibited or human-influenced built-up areas, where mostly past geosites were probably ruined. But the word "probably" has a very important role in this case. With the first step of filtering, all records in settlements were filtered out, although we have lots of examples of geosites that are within built-up areas, even in this area (e.g. the key section of Alsóörs Metarhyolite in the centre of Alsóörs). In order to refine our database, we used the key section list of the Hungarian Geological Survey. There is every geologically important section with coordinates, photos and information, so data was easily insertable into our table. To take into consideration probably less important geosites, we looked over Google Picasa photos uploaded by Internet users of the area. There are lots of pictures that are about different interesting formations, a high cliff, an exciting colourful stone – and because these pictures have mostly accurate coordinates, the plus points also make our database more accurate. Of course, this method was used all over the examined area, and we got geosites that are clearly relevant to tourists as they found them interesting enough to make photos.



Figure 6. On this figure we can see a part of the collected and filtered data in the Balaton Uplands. The map under the potential geosite features is the 1:50 000 geological map of the area

Assessment with GIS

As it could be read in the brief description of the quantitative assessing process, some indicators of the two models (GAM, M-GAM) were evaluated by the help of the tools of GIS. These are the following (from Vujičić et al., 2011):

- **Rarity:** Number of closest identical sites, formations.

Common; regional; national; international; the only occurrence.

- **Viewpoints:** Number of viewpoints accessible by a pedestrian pathway. Each must present a particular angle of view and be situated less than 1 km from the site.
None; 1; 2 to 3; 4 to 6; more than 6.
- **Accessibility:** Possibilities of approaching to the site (inaccessible, by foot, bike, public transport, car).
Inaccessible; low (on foot); medium (e.g. by bicycle); high (by car); utmost (by bus).
- **Additional natural values:** Number of additional natural values in the in radius of 5 km (geosites also included).
None; 1; 2 to 3; 4 to 6; more than 6.
- **Additional anthropogenic values:** Number of additional anthropogenic values in the radius of 5 km.
None; 1; 2 to 3; 4 to 6; more than 6.
- **Vicinity of emissive centres:** the distance from the home of geotourists (e.g. bigger town).
More than 100 km; 100 to 50 km; 50 to 25 km; 25 to 5 km; less than 5 km.
- **Vicinity of important road network:** Closeness of important road networks in the in radius of 20 km.
None; local; regional; national; international.
- **Additional functional values:** Parking lots, gas stations, mechanics, etc. in the radius of 2 km.
None; low; medium; high; utmost.
- **Vicinity of visitors' centre:** Closeness of visitor centre to the geosite.
More than 50 km; 50 to 20 km; 20 to 5 km; 5 to 1 km; less than 1 km.
- **Tourism infrastructure:** Level of additional infrastructure for tourist (pedestrian pathways, resting places, garbage cans, toilets, wellsprings etc.) in the radius of 2 km.
None; low; medium; high; utmost.
- **Hostelry service:** Hostelry service close to geosite.
More than 50 km; 25–50 km; 10–25 km; 5–10 km; less than 5km.
- **Restaurant service:** Restaurant service close to geosite.
More than 25 km; 10–25 km; 10–5 km; 1–5 km; less than 1 km.

Every indicator has 5 possible values to be chosen from and given points of 0.00, 0.25, 0.50, 0.75, 1.00 – they are added after the description in italics.

Performing spatial queries

As we worked with data in a GIS environment, all drawn map features had its own spatial reference. This made our evaluating work a lot easier. The **Rarity** of a formation in case of a geosite can be studied by querying the attribute of the point-feature geosite that contains the geological index. The results informed about the geo-uniqueness of the geosite.

Setting up buffer zones

Most of the appointed indicators evaluation can be carried out this way (*Figure 7*). In the descriptions, we can read about different radii. If we have a source for the other elements of map (line drawing, point features, vegetation), we can take them into consideration when assessing. The number of **Viewpoints** can be counted within a 1 km-radius circle, if we have roads, tracks and relief digitized on the map. After the designation, each can be scored according to its quality (e.g. particular angle of view, quality of pathways). **Additional national values** are especially the potential geosites that we have collected before. **Additional anthropogenic values** are generally human-built tourist attractions: for example, museums, churches, castles, ruins. **Vicinity of emissive centres**, **Vicinity of important road network**, **Additional functional values**, **Vicinity of visitors' centre**, **Tourism infrastructure**, **Hostelry service**, **Restaurant service** can be examined also this way. Then features within radii are mostly the base of evaluation.

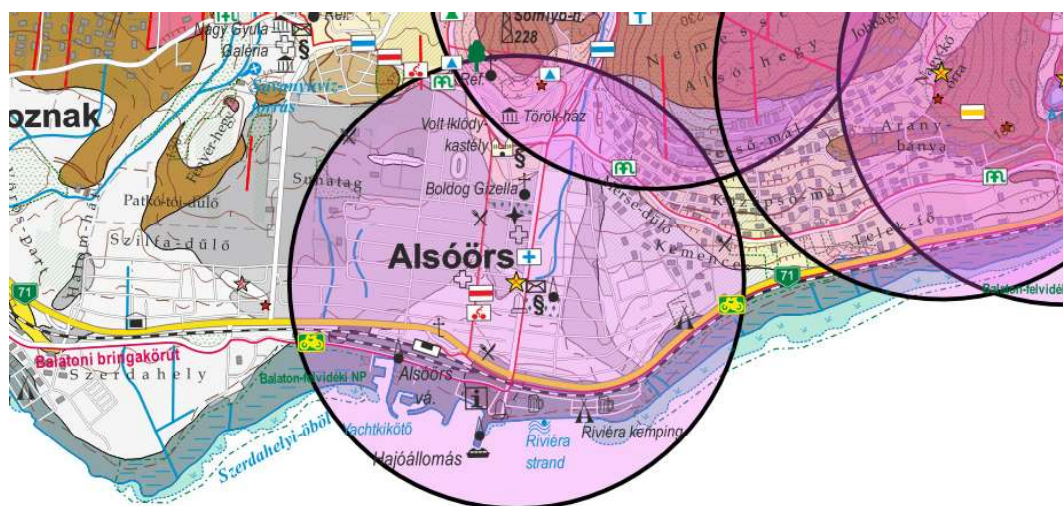


Figure 7. Buffer zones on the geological hiking map around the chosen geosites (yellow star) in Alsóörs

Consequences of the model's uncertainty and the extent of the area

In the original model, some of the indicators were not concretized: e.g. **Tourism infrastructure** had no radius defined. To fix these issues, we examined our digital map in detail, so the radii were defined particularly concerning the designated area. We faced the problem of the reference features especially in the case of **Vicinity of emissive centres** and **Vicinity of important road network**. These indicators are also not so concrete, because the size of emission centres nor the category of the important roads were not defined. In the case of emission centres, Veszprém, Székesfehérvár or Budapest could be chosen, but it does not have a large importance, because most of the geosites get the same scores. The most important roads in the area are M7 motorway and 7 and 8 primary roads. The situation is similar to the emissive centres: nearly all geosites are in the same km zone, so they get the same scores. But it is very important, that these circumstances may be completely different in other areas!

As the examined area is not big and does not encompass greatly infrastructure provided settlements, usually not so many features fall into the buffer zones or circles. If there would be lots of hotels, restaurants, visitor centres, bus stops in the field near to geological values, the counting and filtering would be harder. In this case, each feature was counted easily.

Indicator **Accessibility** was not discussed. Spatial queries can be performed to filter nearby bus stops, tracks or roads, but it makes evaluation process complicated and long. When the features of the geological hiking map are recorded, it is simple to observe surrounding road features (denoted with different visible attributes – line width, colour).

Clustering the assessed geosites

The sum of the indicator's points forms the complete GAM (and multiplied with the tourists' opinion factor M-GAM) value of every geosites. These values can be depicted as linear functions: if the records are in a decreasing (or increasing) order, some clusters or groups of geosites can be distinguished. Depending on the wished number of represented geosites, we can divide our database according to higher values. We used the Natural Breaks (Jenks) method as it minimizes normal deviation between the elements of groups and maximizes the difference between the groups.

Look at the numbers of the geosite assessment of the Csopak area of Balaton Uplands. We started our work in this small area by designating nearly 450 potential geosites. After filtering built-up and mining areas, we had nearly 250. After this step, we have decided to visit these sites. To reduce this number, we categorized the geosites according to geological importance and vicinity of hiking trails. 75 geosites were visited and assessed during fieldwork. With the use of Jenks's method, 24 geosites were chosen to be represented. Most of these geosites were known before, but the relevance of this work is proved by the 2-3 geosites that have no infrastructure built, but it would be worth it.

THE FIRST GEOLOGICAL HIKING MAP OF HUNGARY

We started to design a geological hiking map following the outlines defined in Albert (2004). It was also an attempt to test if an open source GIS software is capable for making a complete printable map. With the applied workflow all map elements became part of a GIS with unique coordinates (but for example pictograms were SVG-edited in graphic

software). To print the map, it was converted into high-resolution raster and the layout was made using CorelDraw. For online publication the QGIS project could be an excellent material.

The map is unique, because except the small map edited by Albert (2002) as a part of a geological excursion guide, no maps of this kind were designed before in Hungary. We hope that geotourists and local people will appreciate this work as it strengthens the connection of locals with their environment, promotes the area in two languages (Hungarian, English) and tries to foster nature conservation.



Figure 8. An excerpt of the geological hiking map surrounding Csopak and Lovas

In the future we plan to make our assessment work more accurate by asking for the opinion of tourists on each geosite. By this interview, the factor of M-GAM will be more accurate, and we will get more realistic scores for every indicator. We also plan to publish this map not just on paper, but on web too. There is also an idea of programming a mobile Android application that contains our map and information about the sights and attractions of Bakony–Balaton UNESCO Global Geopark. These projects are also capable of showing that nature preservation can also be done and developed using digital and GIS approaches!

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I have received my BSc degree on Earth Sciences in 2017, before I have started my studies as a cartographer MSc student. I have started working of the topic of geotourism in 2017. Publications about geotourism assessment, geotouristic maps and the connection between cartography and geotourism prove the necessity of this topic. Among this area, I deal with geographical names and also design traditional printed maps. I am usually a co-organizer of some events of the department (e.g. Open Day, Researcher's Night). I have got a C1 level language exam in English. My degree course greatly enhanced my written and verbal communication and problem-solving skills due to the many presentations, assignments, essays and projects required. In 2018 May I was awarded with the title of 'Outstanding Student of the Faculty of Informatics'.

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