Conserving geoheritage in Slovenia through geomorphosite mapping

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1. Introduction

That difference should not only be tolerated but also celebrated is now commonly accepted. The trend towards valuing diversity has nowhere been more evident than in biology. In recent decades, growing concern about species extinction and habitat loss has led to some important international environmental agreements. The protection of abiotic natural heritage in Slovenia has never been given sufficient attention, and it is considered that it should be protected adequately within the context of other components of the environment.

Slovenia has an extremely complex territory as well as a rich environmental heritage. Therefore, specific instruments and models are indispensable for proper management and appraisal. Maps of abiotic and biotic natural heritage can be very useful tools, allowing the most diverse topics to be represented with simple graphics. A map can, therefore, be defined as a basic introductory instrument for providing information concerning both the complexity and the individual components of a territory (Carton et al., 2005). The study of geomorphosites (Panizza, 2001) and, more generally, of geosites and geoheritage, is a very recent development. To date, investigations carried out on geomorphosites in Slovenia have been limited and have mostly focused on identification, classification, and protection (Agencija Republike Slovenije za okolje, 2009). The problem of cartographic representation has been engaged with but not yet resolved. This article presents the first attempt to map geoheritage in Slovenia.

The introduction presents some main characteristics of Slovenia and recent developments in nature conservation in Slovenia. Special attention is given to the abiotic components of nature. The second part deals with mapping abiotic natural heritage and geomorphosites on the basis of an experimental study carried out in Slovenia by the author. Bled, a world-renowned tourist centre in northwest Slovenia and an area with a large number of natural attractions, was chosen as a case study. Although tourism in Bled is highlighted by its cultural components (a thousand-year-old castle and a church on a small island), natural (in particular, geomorphological) features provide the basis and attractiveness for studying the site.

Geoheritage mapping is seen as an important tool for strengthening the knowledge of geomorphological values; this agrees with the statement by Carton et al. (2005) that "geomorphological maps are useful tools for identification, selection, and assessment of geomorphosites".

2. Main characteristics of Slovenia

The Republic of Slovenia covers 20’273 km^2 with a population of 2’025’000 inhabitants (2007) (Statistical Yearbook of the Republic of Slovenia, 2008). It is situated in the southeastern part of the Alps and on the northernmost part of the Balkan Peninsula. It encompasses four geographical regions: the Alps, Dinaric Alps, Mediterranean and Pannonian basins (Orožen Adamič, 2004). A significant landscape and biological diversity within a relatively small territory is one of the main characteristics of Slovenia. It is greatly supported by different types of climate, geological structure, varied relief and great differences in altitude (from 0 to 2864 m, 600 m being the average). From west to east, the climate changes from (Sub)mediterranean to continental, which is demonstrated by the annual amount of precipitation (2000 to 3000 mm in the Alps in the west, 800 mm in the east of the country).

Fig. 1 Valvasor's map of an intermittent karst lake. One of the first geomorphosite maps (Valvasor, 1689)?

Forests cover almost 1.2 million hectares or about 60% of the territory, which makes Slovenia the third most forested country in Europe. Although forests are without doubt Slovenia's great wealth, they also represent a problem in field research on geomorphological heritage and abiotic nature. Observations are difficult, especially in young forests, and aerial images usually do not penetrate through dense tree crowns.

Due to prevailing carbonate bedrock (42%), appropriate climate and amount of precipitation, karst phenomena are especially well developed in Slovenia. The Sežana-Komen karst region attracted attention of researchers early in history since it was located close to important railway route (Vienna-Trieste).

One of the first and most famous researchers of karst geomorphology and hydrology was J. V. Valvasor (1641-1693). He was the first to professionally describe and present the "functioning" of an intermittent karst lake on a map. He interpreted karst phenomena inaccurately from today's perspective but professionally enough for his times so that his renowned study of intermittent Cerknica Lake (Fig. 1 + 2) earned him membership in the eminent British Royal Society.

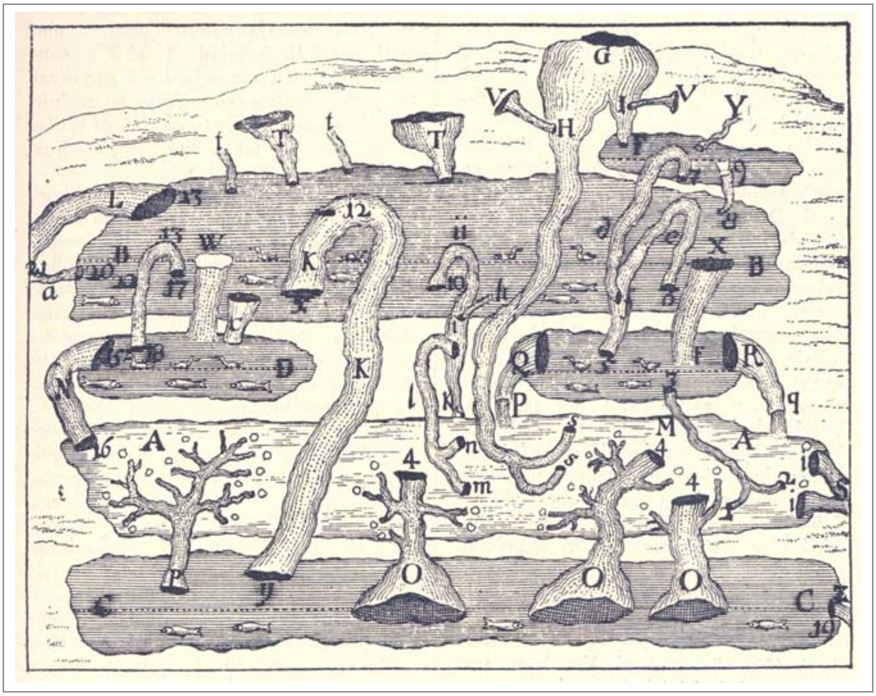

Fig. 2 Valvasor's sketch of the "functioning" of an intermittent karst lake (Valvasor, 1689).

3. Protected areas in Slovenia

3.1 Natural heritage

Due to EU requirements, Slovenia introduced Natura 2000 as a mechanism for the conservation of natural habitats, wild fauna (especially wild birds), and flora. The aim of the network is to assure the long-term survival of Europe's most valuable and threatened species and habitats. It comprises Special Areas of Conservation (SAC) designated by member states under the Habitats Directive, and also incorporates Special Protection Areas (SPAs), which are designated under the Birds Directive (Natura 2000). The average percentage of Natura 2000 areas in EU countries is 15%, whereas in Slovenia it is much higher, over 36% of Slovenian territory (Natura 2000).

This very high percentage is a consequence of the relatively well-preserved natural environment in Slovenia (70% of Natura 2000 are forests).

Natura 2000 is based primarily on biological criteria, which tell little about the diversity of abiotic nature in Slovenia. Although Natura 2000 is primarily designed to maintain certain aspects of biodiversity, protected areas also conserve abiotic nature.

Category	Centres Number	Centres Area (km²)	% of State territory
Wider protected areas			
National park	1	838	4.1
Regional park	3	434	2.1
Landscape park	42	1015	5.0
Smaller protected areas			
Strict nature reserve/wilderness area	1	0.02	0.0
Nature reserve	52	69.8	0.3
Natural monument	1217	155.5	0.8
Total	**1316**	**2320**	**11.4**

Table 1 Types, numbers, and size of protected areas in Slovenia according to IUCN categories (Agencija Republike Slovenije za okolje, 2009, Lampič & Mrak, 2007, Statistical Yearbook of the Republic of Slovenia 2008). Note: the total area is smaller than the sum of partial numbers, because some smaller protected areas are part of wider protected areas.

Nature protection in Slovenia is defined through the Nature Conservation Act of 1999 (Zakon o ohranjanju narave, 2004). According to the act, the wider protected areas (national parks, regional parks, landscape parks) cover approximately 2300 km² or around 11% of Slovenia (Agencija Republike Slovenije za okolje, 2009). The percentage of protected areas in comparison to other European countries ranks Slovenia near the bottom of the international scale (Berginc, 2007).

3.2 Abiotic natural heritage

The Slovenian Nature Conservation Act defines 10 different kinds of valuable natural features (Erhartič, 2009): geomorphological, subsurface geomorphological, geological, hydrological, botanical, dendrological, zoological, ecosystem, landscape, and designed nature. At least four of them correspond to the term "geodiversity" (diversity of abiotic nature) (Gray, 2004): surface geomorphological, underground geomorphological, geological and hydrological valuable natural features. However, other types of valuable natural features may also contain abiotic nature.

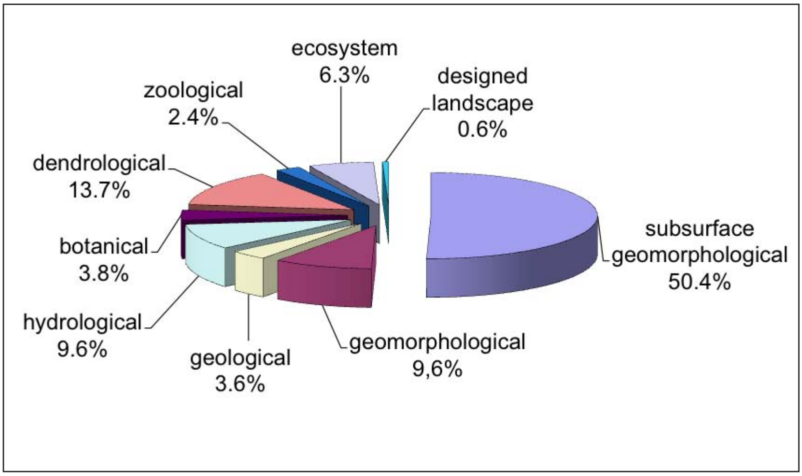

Fig. 3 Valuable natural features in Slovenia in 2008 (Agencija Republike Slovenije za okolje, 2009).

There are about 19'000 valuable natural features in Slovenia (Agencija Republike Slovenije za okolje, 2009). Figure 3 shows that half of them are underground geomorphological valuable features because all karst caves are declared as (subsurface) valuable natural features of national importance. The large number of trees as a natural value is also not difficult to explain. Surface geomorphological and hydrological natural features follow, in third and fourth place. Abiotic natural values as defined above represent 73% of Slovenia's valuable natural features.

Around 85% of valuable natural features can be shown as points (caves, erratic boulders, trees), and the rest of them are indicated as areas, mostly very small. There are only 338 areas larger than 1 km² (Agencija Republike Slovenije za okolje, 2009). Table 2 shows the ten largest valuable natural features.

Slovenia has a good on-line register of valuable natural features, designed and maintained by the Environmental Agency of the Republic of Slovenia and the Institute of the Republic of Slovenia for Nature Conservation. Unfortunately, the list does not indicate why a specific feature was declared as a natural value. However, the expert evaluation criteria are exceptionality, representativeness, complexity, conservation status, rarity and ecosystem, and scientific or evidential importance; aesthetic and cultural values are not among them. This is the main problem of the Slovenian Nature Conservation Act and has consequences on the nature conservation system as a whole, as well as on geomorphosite assessment and mapping. According to the act, specific landforms or sites cannot be declared valuable natural features due to their outstanding beauty (aesthetic aspect) or cultural significance.

Name	Type	Feature (form)	Area (km^2)
Pokljuka	geomorphological	karst mountain plateau	136.64
Jelovica	geomorphological	karst mountain plateau	109.63
Nanos	geomorphological, geological	thrust structure	91.01
Kraški rob	geomorphological, botanical, zoological	thrust structure	65.05
Menina planina	geomorphological	karst mountain plateau	52.34
Krakovski gozd	zoological, botanical	flooded forest	46.36
Mura	hydrological, zoological	river	43.97
Vrata	geomorphological	glacier valley	43.87
Cerkniško polje	geomorphological, hydrological	karst polje (with intermittent lake)	35.44
Trnovski gozd	geomorphological, botanical	thrust	32.49

Table 2 The ten largest valuable natural features by surface. Their total area is 656.8 km^2, which is 3.24% of the national territory. The large majority of them are geomorphological features (Agencija Republike Slovenije za okolje, 2009).

3.3 Holistic approach

Although nature conservation in Slovenia is still largely the domain of biologists, the situation is slowly changing. Conservation is moving from the protection of species, to the protection of biodiversity, and towards a holistic approach to nature conservation (Serrano & Ruiz-Flano, 2007), which takes into account bio-, geo-, and landscape diversity. Some non-governmental organisations and the Scientific Research Centre of the Slovenian Academy of Sciences and Arts have undertaken the initiative with regard to a holistic concept.

The changes in conservation concepts, both in Europe and in Slovenia, and the incorporation of biodiversity have led to a greater understanding of the role that the abiotic components of a landscape play in determining value, an aspect without which it is not possible to conserve nature. Indeed, protected areas and places of maximum interest are often defined as such because of the abiotic elements that make up these outstanding landscapes (Serrano & Ruiz-Flano, 2007). Abiotic elements and dynamics are considered important, not only for sustaining life, but also for supporting the smooth functionality of terrestrial and marine systems and the conservation of habitats and landscapes.

Following these concepts, a systematic study of abiotic nature was also recently initiated in Slovenia. The assessment should be conducted following various steps indicated by a number of authors (Panizza, 2001, 2003; Pereira et al., 2007; Rodriguez, 2008):

1. Identification, inventory of heritage;
2. Classification, evaluation (qualitative and quantitative assessment);

3. Mapping (cartography);
4. Protection, conservation, preservation;
5. Presentation, interpretation, promotion.

The manner of accomplishing all these steps is quite an important issue because it involves the communication of a message from a scientific source (the first four phases) to the general public, who are the potential "users" of geoheritage (the fifth phase). In its practical (case study) part, this article focuses in particular on the third step of analysis: mapping geoheritage.

4. Mapping geoheritage

Compared with the research carried out in geomorphosite assessment and promotion, geomorphosite mapping has not received the same consideration. Today, scientists from various European countries are engaged in geomorphosite mapping (Coratza & Regolini-Bissig, 2009). It is important to have detailed geomorphological maps that provide fundamental data for meticulous description of sites. Large-scale geomorphosite mapping should, therefore, be considered an elementary part of the assessment process when carrying out inventories (Serrano & Gonzales-Trueba, 2005; Perreira et al., 2007; Coratza & Regolini-Bissig, 2009). *General overview maps* (Fig. 4) can be used in various areas, such as hazard assessment, spatial planning, tourism purposes (planning of interpretative trails), and so on. At the end of the inventory process, it may also be useful to create *thematic overview maps* to synthesize the distribution of various parameters that were assessed (e.g. glacial geomorphosites, punctiform geomorphosites) (Coratza & Regolini-Bissig, 2009).

The first map presented here (Fig. 4) shows the general distribution of geomorphological heritage in Slovenia. Simple symbols are used to indicate the location of geomorphosites on a simple digital elevation model (DEM) map. The variety of symbol shapes and colours produces extra information for immediate comprehension. Each geomorphosite on the map has a number in the corresponding table (not shown in figure 4) with additional information such as name, ID number, type, and a short description (similar to those shown in table 2).

There is no space for any other information on such a map. Therefore, small-scale maps are in most cases just *index maps.* However, more advanced maps have reference symbols that are specific ideograms with a precisely coded meaning, similar to those used in nature guides or on notices (Carton et al., 2005). These symbols allow an initial subdivision of geosites into various categories (e.g. a large or small symbol for a site of national or local importance, a wave to show a hydrological feature, an ammonite to show a geological-paleontological site or feature, etc.) that may interest the user.

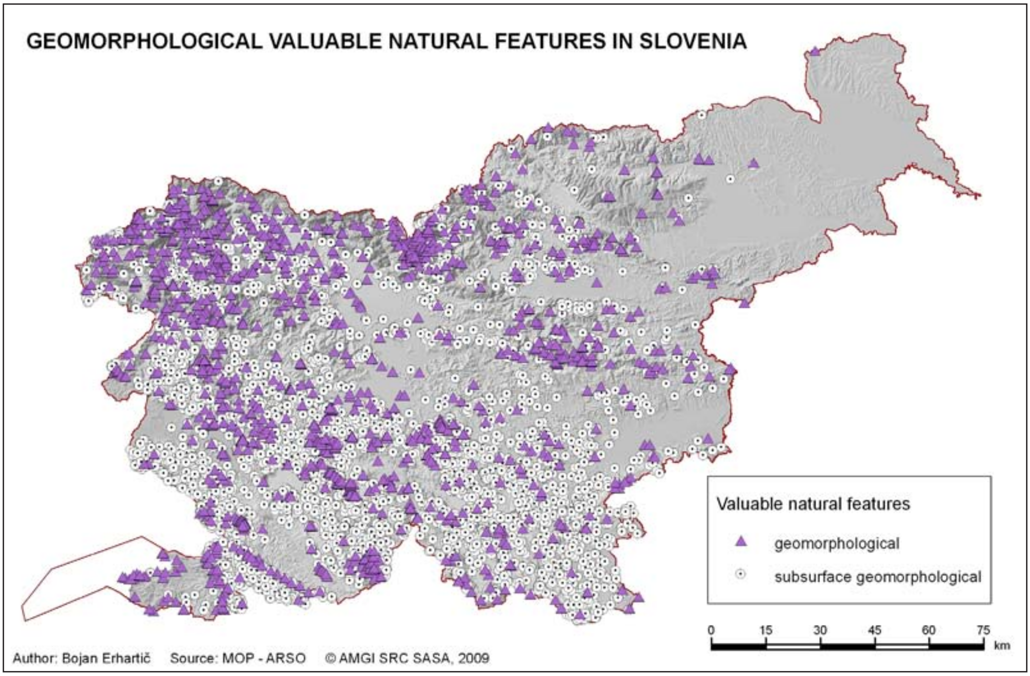

Fig. 4 Map showing geomorphological valuable natural features. Because of the small map scale, geomorphosites are presented only with punctual symbols. The largest concentration occurs in mountain and karst regions.

Map scale is an extremely important aspect of mapping. With regard to geomorphosites, a map can be at either a small or a large scale, but it is appropriate to have a limit between the two extremes. Carton et al. (2005) propose that maps at a 1:200'000 scale or less can be used as geomorphosite indexes (distribution of geomorphosites in a country or region), whereas those at larger scales can be used for showing geomorphosites in detail.

5. Case study of Bled

5.1 Bled: short overview

The lakeside settlement of Bled (500 m a. s. l.) is one of the oldest tourist centres in Slovenia. It lies in a basin at the eastern foot of the Julian Alps, where the Bohinj glacier cut several hills, created the lake hollow and several moraine deposits. These Ice Age gravel mounds also constitute the terraced region south and east of Bled. Lake Bled was created only about 14,000 years ago when water flooded the depression left by a receding glacier. It was once much larger and twice as deep as it is today, with an effluent at its eastern end. The current effluent stream, the Jezernica, etched its way south and since then the lake started decreasing in size. Today, it is 2100 m long and 30 m deep. Its surface temperature in summer is 24°C and it remains warm enough for swimming until the autumn. On the geological fault-line near the lake there is a thermal spring which has been tapped to supply the indoor swimming pool (Gosar & Jeršič, 1999).

The first visitors to Bled were pilgrims visiting the Church of St Mary on the island. Bled was also frequented by the nobility due to its outstanding beauty and the presence of thermal springs. Tourism in Bled would never have developed if Ignac Novak, an administrator of Bled Castle, had had his way. On several occasions in the late eighteenth century, he suggested that the lake should be drained for farmland and the clay from the lakebed used for making bricks. Luckily, his ideas were rejected by the Carniolan Assembly (Janša-Zorn, 1984).

It was the Swiss-born physician Arnold Rikli that helped Bled attain worldwide acclaim by building and developing a spa, and introducing a special treatment regime. Rikli worked at Bled more than fifty years (1854-1916), and the number of visitors increased dramatically when nearby rail lines were opened (Janša-Zorn, 1984).

Although Bled has been settled for more than one thousand years, it was established as a town in 1960, when five villages, which spread around the lake and are separated by several geomorphosites (moraines and hills, Castle Hill (599 m) among them), were united. Due to the fast growth of the city, many interesting abiotic and biotic natural features were covered or lost (e.g. wetlands, moraines and terraces).

Fig. 5 Bled, a world-renowned tourist centre with a unique mixture of natural and cultural elements and a large number of geomorphosites (photo: Bojan Erhartič).

5.2 Methodology

To date, investigations carried out on geomorphosites in Slovenia have been limited and have mostly focused on identification and classification. This article presents some first attempts to map geoheritage. The use of Geographical Information Systems (GIS) is acquiring ever-increasing importance because they allow useful elaborations, continuous updating of data, and easy interaction with the final user (Carton et al., 2005). This study uses geomorphologic mapping to analyse abiotic natural values in a small but diverse and interesting tourist area in the foothills of the Alps. The abiotic components of nature are essential to identify the qualities of a space in terms of tourism resources.

The method used is somewhat different from those recommended by Italian geomorphologists (Castaldini et al., 2005) because the first step was not performed: the creation of a "classical" geomorphological map. The database of the Environmental Agency of the Republic of Slovenia was used as a basis. All biotic features were excluded, and only the abiotic valuable features were analysed. The *map of abiotic natural features* can be seen in figure 6. We focused mainly on the accuracy and reliability of the data from the institute's database. Therefore, spatial information was gathered from orthophoto images and fieldwork in order to accurately locate and assess geomorphosites. After making a database (compilation and evaluation of an inventory), a *map of geomorphosites* (Fig. 7) was created and compared to the map of abiotic natural features.

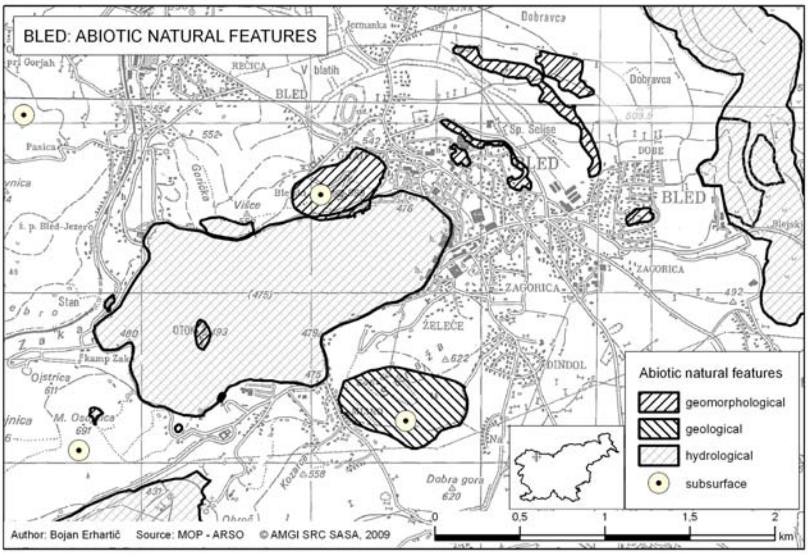

Fig. 6 Map of abiotic valuable natural features.

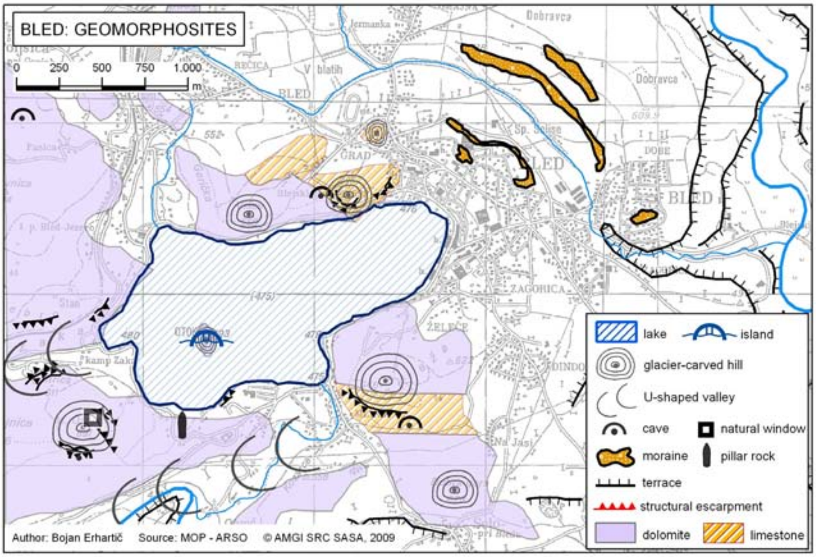

Fig. 7 Map of geomorphosites.

5.3 Discussion

On large-scale maps, geomorphosites are best shown by means of the more or less traditional symbols used in detailed geomorphological maps (Fig. 7). Only the symbols showing the form or set of forms making up a geomorphosite are depicted, whereas all the other elements of the landscape are omitted. The topographic basis and its scale were selected on the basis of the goals of the documents and the dimensions of landforms that are represented (Carton et al., 2005). Furthermore, on this large-scale geomorphosite map (Fig. 7) each geomorphosite has been numbered progressively and referenced in the corresponding table (not shown in figure 7).

Aim of the map

Although Carton et al. (2005) proposed a distinction between two categories of maps depending on the user (maps for specialists and maps for non-specialists), it was decided to create a *general overview map* (Fig. 7) without further interpretation purposes. The aim was only to synthesize the distribution of different parameters that were assessed. This map does not have specifically-defined final users, but is in fact a strong visual communication tool because it reveals distribution patterns that are much more difficult to identify from the written text of an inventory card (Coratza & Regolini-Bissig, 2009).

The geomorphosite map gives a general overview of the abiotic components of the most important tourist destination in the Slovenian Alps and may represent a basis for further work to local authorities. Users can also be other specialists or non-specialists, but this is not a (geo)tourist map in the strict sense because it does not contain tourist information. Some practical information (e.g. directions, parking, paths, and viewpoint) is an essential part of geotourist maps. However, as Bissig (2008) said, orientation and tourist information is the map's secondary function. Its primary function is the communication of spatially relevant themes and processes that contribute to the formation of a geomorphosite or a geomorphological landscape. An essential part of the morphogenesis explanation of the case study area is understanding the movement of the retreating Bohinj glacier at the end of Pleistocene era (Šifrer, 1969, 1992).

Content of the map

Quite obvious hills or arcs of terminal moraines can be seen in and around Bled. They consist of three successive stages of the retreating glacier. At the edges of the Sava River terraces, smaller and larger parts of older moraines occur on the surface in some places. Those parts have not been proclaimed valuable natural features (they are not shown in figure 6 as geomorphological heritage). Even so, they were evaluated very highly due to their outstanding scientific and educational value. Thus, they were recognised as geomorphosites (Fig. 7).

In contrast, the fossil site (a geological natural value) was excluded from the geomorphosite map for two reasons: because it is difficult to find the fossil site, and it would be problematic to promote paleontological heritage because uncontrolled exploitation could lead to devastation of the site. Some layers of rock types (limestone and dolomite) were put on the geomorphosite map instead, so the user could easily see and understand the difference between types of bedrock.

Design choices

Digital geomorphosite mapping has many advantages. The scale problem is less important because GIS allow the reduction or amplification ratio to be automatically obtained. The most important map components to be discussed are background maps, symbols, and a legend.

The geomorphosite map used some geomorphological *symbols,* although Carton et al. (2005) did not recommend them. Maps for non-specialists are designed to be easily understood while remaining an effective means of conveying scientific information.

In order to attain this goal, the 1:25'000 *topographic maps* were used as a *background* (1:50'000 is also useful) because they are known to and sometimes used by tourists, especially hikers. The topographical background also gives users precise locations, helping them orient themselves. Thus, most users can presumably interpret them. A simplified topographic map was not used as a base, but the transparency of the background was increased. A topographic basis was also used in order to emphasize the connection between geomorphological heritage and settlement. The impact of urbanisation on the natural heritage is clearly visible as well as the influence of geoheritage on the pattern of settlement. Thus, it can be useful for spatial planning and conservation needs.

Visual elements highlight features on a map. Colours can be used in two ways: according to the description of various types of landforms (Fridl, 1999) and processes (karst, glacial, hydrological, structural), or according to the importance of a specific element. The second approach was chosen in this case study. It enabled the use of more intense colours for the prominent landscape features (e.g. moraines and structural forms). The lake and the island are the most important distinctive features, and so their symbols were placed at the top of the *legend.*

Because Slovenia (part of Yugoslavia until 1991) has a quite long tradition of geomorphological mapping, some symbols proposed by Natek (1983) were used (e.g. terraces and structural escarpments). When a geomorphosite is punctiform or linear, it is easy to choose which forms will be represented and what their relative *symbols* will be. It is, however, more difficult to choose the landscape elements when it is an areal (polygon) type of geomorphosite (Carton et al., 2005). The most important question is how to present megaforms (e.g. U-shaped valleys or glacier-carved hills) as well as some mesoscale (e.g. erratic boulders) or even microscale forms on the same geomorphosite map. At the international level, at present there are a great variety of geomorphological legends, which differ from one another in their content, adopted symbolism, and scale representation because a single, universally recognised legend has not yet been implemented (Gustavsson et al., 2006, Coratza & Regolini-Bissig, 2009). International guidelines for establishing a common mapping standard are needed and should be discussed in the near future.

6. Conclusion

The mapping of geomorphosites is an important tool for territorial management as well as an effective means of communication and spreading knowledge, especially to raise awareness among the general public. A geomorphosite map can be used to prepare development plans at both the national and local levels. Managers of protected areas may use information from the map for establishing guidelines and a management plan, monitoring, directing tourism development, and promoting the ever-changing abiotic nature.

Growing sensitivity to numerous features of the environment has led geomorphologists to tackle the problem of in-depth study, preservation, and appraisal of geomorphological heritage. There is a growing awareness of the importance of geomorphological values concerning not only the scientific knowledge of a territory but also its environmental management and production activities. The scientific aspect has often added greater value to the appraisal of areas with a strong attraction for tourists.

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