ARTICLES

GEODIVERSITY AND GEOMORPHOSITE RESEARCH IN SLOVENIA

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ABSTRACT
Geodiversity and geomorphosite research in Slovenia
Slovenia's geodiversity, or its abiotic natural diversity, becomes more and more significant when considering regulations on nature conservation. This article presents theoretical background information to the study of geodiversity and geomorphological heritage and the current state of this field in Slovenia. The first quantitative evaluation of geomorphological heritage in Slovenia, which was carried out in the Triglav Lakes Valley, is also presented. The significance of regions with a high concentration and diversity of landforms is presented. Some inconsistencies in the current register of natural values are described and recommendations are presented for adding to this register.

KEY WORDS
geography, geomorphology, geodiversity, geomorphosites, nature conservation, Triglav Lakes Valley, Slovenia

IZVLEČEK
Preučevanje geodiverzitete in geomorfološke dediščine v Sloveniji
Geodiverziteta ali pestrost nežive narave v Sloveniji vse bolj pridobiva na pomenu pri vprašanju zakonskega varovanja narave. Predstavljena so nekatera teoretska izhodišča za preučevanje geodiverzitete in geomorološke dediščine ter stanje na tem področju v Sloveniji. Predstavljeno je tudi prvo kvantitativno vrednotenje geomorfološke dediščine v Sloveniji, izvedeno v Dolini Triglavskih jezer. Izpostavljen je pomen območij z veliko gostoto in raznovrstnostjo reliefnih oblik. Ugotovljena so bila nekatera neskladja z obstoječim registrom naravnih vrednot ter podani predlogi za dopolnitev le-tega.

KLJUČNE BESEDE
geografija, geomorfologija, geodiverziteta, geomorfološka dediščina, varstvo narave, Dolina Triglavskih jezer, Slovenija

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1 Introduction

In the past two decades, the trend toward describing and evaluating natural diversity around the world and in Slovenia has been strongest in biology (Serrano and Ruiz-Flaño 2007) because concerns about species extinction and habitat loss have grown. The concept of biodiversity was introduced in 1988 as a scientific term to define the variability of the Earth's living organisms, its »biological diversity« (Wilson 1992), and was intended to include »the diversity within species, between species and of ecosystems« (Hawksworth 1996). Its use became widespread as a result of the Earth Summit held in Rio de Janeiro in 1992, which was held in order to encourage analysis of conservation of biodiversity and related issues. Biodiversity promotes the idea that the world is biologically diverse, that there are significant threats to this biological diversity, and that there is therefore a need to take action to conserve it. It quickly became obvious to geoscientists that there must be an equivalent to biodiversity to describe the variety of non-living or abiotic natural wealth. The first uses of the term »*geodiversity*« occurred in 1993 in publications from Germany and Australia (Wiedenbein 1993; Sharples 1993; Gray 2008). Thus, some researchers quickly realized that it is possible to consider geology, geomorphology, and hydrology in much the same way as biology; that is, planet Earth is very diverse in these senses as well, and this diversity is also valuable and threatened, and there is a need to conserve it. Thus the concept of geodiversity took its place as a tool for managing protected areas, often in contrast to the term *biodiversity* (Cañadas and Ruiz-Flaño 2007). In Slovenia, the term did not appear in professional literature until 2007 (Erhartič 2007).

The term *biodiversity* is still more common than the term geodiversity, which is shown by the two terms' use on the World Wide Web. Using the Googlefight webpage to compare biodiversity (with 4.3 million hits) and geodiversity (with around 17,400 hits) on 22 January 2012 showed that the difference is a factor of nearly 250.

The concept of conservation and management of natural areas has changed over time. Broadly speaking, the main phases have been (Skoberne 2005):

- Conservationist, with implementation of landscape and monumental concepts involving the most outstanding visible elements of natural areas (e.g., trees, caves, waterfalls);
- Biological, with protection of species being placed in the foreground (over time, activities were extended to include ecosystems);
- Holistic, with extension of understanding ecosystem protection to a global level that includes habitats and landscapes as visible elements of the multiple relations between living beings, including humankind, and the abiotic environment.

These changes in conservation concepts 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 impossible to conserve nature. Indeed, protected areas are often defined as such because of the abiotic elements that make up these outstanding landscapes. It is within this framework that new terms have been coined and concepts such as geodiversity have been created.

In Slovenia, the first known example of conscious nature conservation was the protection of the virgin forest *Rajhenavski pragozd* in 1892. Despite over a century of tradition, however, management of natural areas is only now moving from the second, biological and ecosystem phase, to the third, holistic phase or paradigm.

2 Geodiversity

The Australian Heritage Commission report of 2002 defines geodiversity as »the natural range (diversity) of geological (rocks, minerals, fossils), geomorphological (landform, processes) and soil features. It includes their assemblages, relationships, properties, interpretations and systems« (Gray 2004, 8;

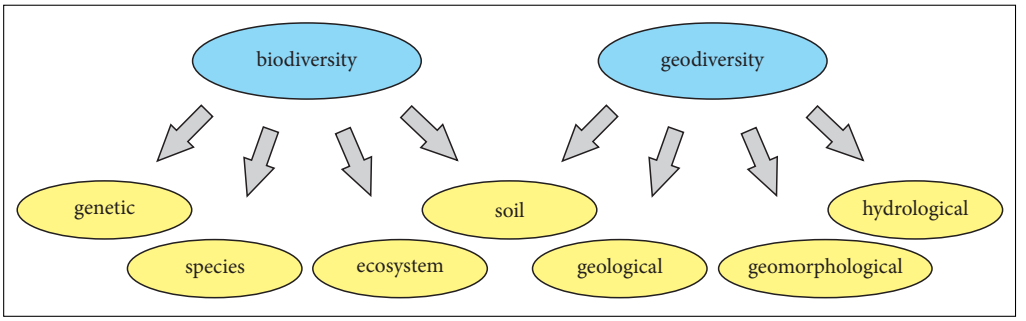

Figure 1: Levels of biodiversity and geodiversty (Erhartič 2011, 28).

Internet 1). The British definition is similar, except that it also includes people and culture: »It is the link between people, landscapes and culture; it is the variety of geological environments, phenomena and processes that make those landscapes, rocks, minerals, fossils and soils which provide the framework for life on Earth« (Gray 2004, 7). In marked contrast to the clear and precise definition of biodiversity, which includes a concept of hierarchical levels – genes, species and ecosystems (Figure 1) – geodiversity has shown a conceptual weakness that has left it adrift in various fields. The concept of geodiversity as »the variety of abiotic nature« (Gray 2004) includes a plethora of interrelated elements on the land surface and in the seas and oceans. It has also led to attempts to formulate more integrative definitions that try to take into account all the elements involved in the structure and physical processes of the land surface. Sharples (2002), on the other hand, includes not only geological, geomorphological, and soil elements, but also the interrelated character of their links, assemblages, properties, systems, and processes. The most integrative vision is that of Kozlowski (2004, 834) who defines geodiversity as the »natural variety of the Earth's surface, referring to geological and geomorphological aspects, soils and surface waters, as well as to other systems created as a result of both natural (endogenic and exogenic) processes and human activity.«

Slovenians use a somewhat simplified definition (Erhartič 2007, 60): »geodiversity is the diversity and complex connection of features and processes in the geology, geomorphology, hydrology, and soil geography of a particular area«; it is also understood as the diversity of non-living nature.

There is a natural tendency to think of wildlife as being fragile and vulnerable and therefore in need of conservation, whereas rocks, mountains, and landforms are seen as stable, static, and much too prolific to ever be endangered. The world's geodiversity is of value in several respects but is threatened by many human activities (Gray 2004). Pressures on geodiversity arise principally from planning developments and land-use changes. These may damage key features, impair their visibility and accessibility, or fragment the interest. There is therefore a need for *geoconservation*, but the objectives and methods of geoconservation need to take the various elements of geodiversity into account. For example, the conservation of soils needs to be approached very differently from the conservation of fossils. Important geomorphological sites can be protected by legislation, but soils and landscapes in the wider countryside are better conserved by policy development and partnerships (e.g., in agriculture). Slovenia lacks a holistic perspective on landscape because this is dealt with by sectors within various ministries (e.g., the Ministry of Infrastructure and Spatial Planning, the Ministry of Education, Science, Culture, and Sport, and the Ministry of Agriculture and the Environment). Only in the past few years has Slovenia focused more on studying the issues of geodiversity and geoheritage, primarily geomorphological heritage (geomorphosites) (Erhartič 2007; 2010a; 2010b; Zorn, Erhartič, and Komac 2009; Komac, Zorn, and Erhartič 2011), although awareness of geological heritage (geosite) is older (e.g., Rotar 1991; Hlad 1998; Hlad and Šolar 1998; Kavčič and Peljhan 2010; Peljhan, Gorjup-Kavčič, and Benčina 2011).

The geodiversity concept highlights the sensitivity of abiotic elements and dynamics and the value of the natural, geological, geomorphological, pedological, and hydrological factors in nature conservation and land planning and management. However, this does not imply a focus on concrete sites (e.g., geosite and geomorphosites), but rather on a set of elements found within a stretch of the land continuum or in a region as a whole. According to Gray (2005), geodiversity is a means for inclusion of natural diversity in conservation, planning, and education through different forms (e.g., geotopes, geomorphosites, geoparks, and protected landscapes). The objectives and methods of geoconservation vary, depending on which element of geodiversity is being considered.

3 Geomorphological heritage

Of course, it is not necessary to protect all geodiversity because that would lead to pragmatic problems due to society's needs to use certain resources. Thus it is necessary to highlight, evaluate, and protect the most important or most valuable parts of abiotic nature.

Landforms are one of the most widespread, immediately recognizable, and attractive non-living natural elements of the landscape, which have always aroused interest among people due to their beautiful, exceptional, or unusual appearance. By selecting interesting, memorable shapes, people unconsciously endow them with some meaning or value. These forms thus become heritage, or (with professional evaluation) a value. Its attributes are those that give it value and allow the landform to be declared a geomorphological natural value.

Geomorphological heritage (e.g., Hribar 2010) thus entails phenomena and processes to which value can be ascribed: scientific, aesthetic, historical, tangible, and intangible cultural, social, or economic value, depending on people's perceptions or the needs of a given study. Evaluation is personal and depends on the awareness and knowledge of an individual and the entire society (Hlad 2002). A given landform becomes a natural value only if it also contains a social component, and if the geomorphology and nature conservation professionals recognize it as a value and ascribe it the status of a value. However, because society develops and changes over time, and with it also the criteria and measures, values are also subject to change (Šmid Hribar 2008). The problem of evaluating nature and natural values is that, regardless of the evaluation method used, it is practically impossible to exclude the subjective component (Erhartič 2010a).

In international literature, the term *geomorphosite* has come into use for geomorphological heritage. Panizza (2001, 4) defines this term as »a landform to which a value can be attributed.« Regardless of the fact that terms change, parts of nature that have been recognized as such remain. What is essential is that they contain special values (Berginc 2006). With non-living heritage, researchers first primarily studied the scientific value of forms and phenomena (Panizza and Piacente 1993; Rivas et al. 1997; Bruschi and Cendrero 2005; Coratza and Giusti 2005; Serrano and Gonzales-Trueba 2005) because they were merely used to support the inventorying of heritage and the analysis of environmental impacts (Reynard et al. 2007). Scientific criteria were soon joined by cultural, ecological, economic, and aesthetic criteria of evaluating non-living nature (Panizza and Piacente 1993; Reynard et al. 2007). In order to reduce subjective influence and enable comparison of geomorphological heritage in various parts of the world, a number of quantitative methods of evaluating geomorphological heritage have developed in recent years (e.g., Panizza 2003; Coratza and Giusti 2005; Serrano and Gonzales-Trueba 2005; Pereira, Pereira, and Caetano Alves 2007; Reynard et al. 2007). Which evaluation method is the most appropriate depends on the research goals (Erhartič 2010a). Until recently, this type of (quantitative) evaluation had not been present in Slovenia (Erhartič 2010a; 2011). The first protected area where it was carried out was Triglav National Park, which is also the only Slovenian national park (Erhartič 2011; chapter 5.1).

4 Geodiversity in Slovenia

The Republic of Slovenia covers 20,273 km^2 and encompasses four macro-geographical regions: the Alps and Dinaric Alps, and the Mediterranean and Pannonian basins (Orožen Adamič 2004). Significant landscape and biological diversity within a relatively small territory is one of Slovenia's main characteristics. It is greatly supported by different types of climate, geological structure, varied relief, and great differences in elevation. Due to prevailing carbonate bedrock (43%), an appropriate climate, and the amount of precipitation, karst phenomena are especially well developed in Slovenia. The Sežana-Komen karst region, known also as the Classical Karst, attracted the attention of geotourists as early as the Middle Ages (Zorn, Erhartič, and Komac 2009).

Even though geodiversity has not yet been systematically studied in Slovenia, it can be concluded on the basis of natural-geographical landscape elements that the level of geodiversity is high in Slovenia because a large number of geological, geomorphological, and hydrologic phenomena are manifested in a small area.

Slovenia's nature conservation system is thematically oriented toward three fields: natural assets (values), plant and animal species, and ecosystems. Due to EU requirements, Slovenia introduced Natura 2000 as a mechanism for the conservation of natural habitats, fauna (especially 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 (Internet 2). The EU describes habitats as »terrestrial or aquatic areas differentiated by their geographical, abiotic and biotic characteristics, whether they be wholly natural or semi-natural« (Internet 2). Thus habitats include abiotic and spatial components. The variety of abiotic elements forming habitats can also be referred to as geodiversity. The framing of the concept of geodiversity in this context is of special interest because it reflects an understanding of natural diversity, and links the concept to development of conservation policies and management of natural protected areas and natural heritage in national and transnational areas, such as Natura 2000 in Europe. Even though Natura 2000 has thus been based on biological criteria, the determination and management of these areas also entails the study and preservation of geodiversity.

The average percentage of Natura 2000 area in EU countries is 15%, whereas in Slovenia it is much higher, over 36% (Internet 2). This very high percentage is a consequence of the diverse landscape/abiotic compounds and relatively well-preserved natural environment in Slovenia. The surface contains a great diversity of rocks. Sedimentary rocks originate in various geological periods and are thus extremely diverse, which is why the soils are also extremely diverse (Jeršek and Vidrih 2009). Great diversity can also be observed with climatic conditions, which especially depend on distance from the sea, elevation, and the quantity of precipitation. These factors are reflected in exceptionally great geodiversity.

Due to the large share of carbonate rocks, geodiversity in Slovenia may be the greatest when it comes to karst forms. The karst features in the Slovenian Karst (*Kras*) are so distinct and characteristic that the Slovenian-based term *karst* has become standardized in international terminology for this type of landform (Jeršek and Vidrih 2009).

The possibility of measuring and quantifying geodiversity has been discussed since the beginning of geodiversity research (Serrano and Ruiz-Flano 2007). It is accepted that the effectiveness of the incorporation of geodiversity in land management depends on the capacity to understand and evaluate it. Nevertheless, the applications of the term and the theoretical reflections thereof have not been accompanied by systematic evaluation of geodiversity assessment methods.

One of the first attempts to evaluate parts of geodiversity in Slovenia applied to the Soča River and the project of constructing a hydroelectric power plant at Kobarid (Peterlin and Sedej 1965; Orožen Adamič 1970). Peterlin and Sedej (1965) used an exclusively descriptive evaluation method, whereas Orožen Adamič (1970) used a simple method to numerically illustrate the »value« and thus reduce the subjective influence of evaluating nature. This resulted in a list of factors that were able to be assessed with a specific unit of measurement.

5 Geomorphosites in Slovenia

In Slovenia, natural heritage is defined as a part of nature »that a society of a specific time and place recognizes as value« (Inventar … 1988). In 1999, the Nature Conservation Act (Zakon o ohranjanju … 1999) eliminated the term »natural heritage« and introduced a new one: »natural value/valuable natural feature.«

Even though 170 years ago the first initiative to protect natural sites (Praprotnik 2004; Skoberne 2007) referred to the aesthetic experience of nature and all of the old nature conservation legislation was familiar with natural beauty or the aesthetic aspect, the currently valid Nature Conservation Act (Zakon o ohranjanju … 1999; 2004) does not mention any aesthetic criteria for evaluating nature. At the management level, this severely encumbers the evaluation of nature and defining heritage. According to this act, »natural values shall encompass all natural heritage in the territory of the Republic of Slovenia« (Zakon o ohranjanju … 2004) and »in addition to a rare, valuable or well-known natural phenomenon, a natural value shall be any other valuable phenomenon; component or part of living or non-living nature; natural area or part thereof; ecosystem; landscape; or designed landscape.«

The Slovenian Nature Conservation Act (Zakon o ohranjanju … 2004) defines ten different kinds of natural values (Erhartič 2009). At least four of them correspond to the term »geoheritage«: surface geomorphological, underground geomorphological, geological, and hydrological natural values. However, other types of natural values may also contain abiotic nature.

There are about 19,000 natural values in Slovenia (Internet 3). Figure 2 shows that half of them are underground geomorphological values because all karst caves are declared as (subsurface) natural values of national importance (Zakon o varstvu … 2004). Surface geomorphological and hydrological natural values follow, in third and fourth place. Abiotic natural values as defined above represent 73% of Slovenia's natural values.

Around 85% of natural values can be shown as points (cave entrances, erratic boulders, trees), and the rest of them are indicated as areas, mostly very small. There are only 338 areas larger than 1 km^2 (Internet 3). The total area of the ten largest natural values is 656.8 km^2, which is 3.24% of the national territory. The large majority of them are geomorphological values: karst mountain plateaus, thrust structures, glacier valleys, and karst poljes (Internet 3).

5.1 Example of evaluating landforms in high mountain areas

From 2008 to 2011, an extensive study (Erhartič 2011) was conducted on the geodiversity and geomorphological heritage in the oldest Slovenian protected area, from which the Triglav National

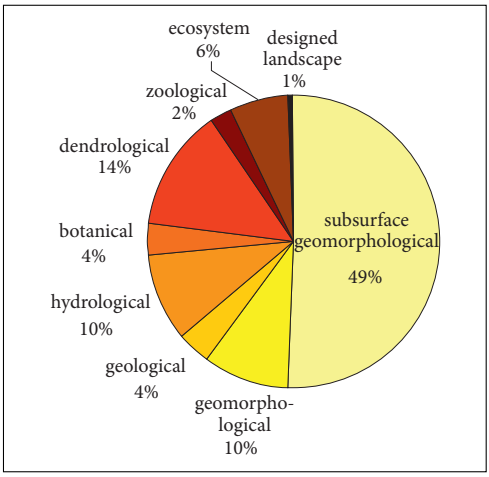

Figure 2: Natural values in Slovenia (Internet 3).

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Figure 3: The central part of the Triglav Lakes Valley.

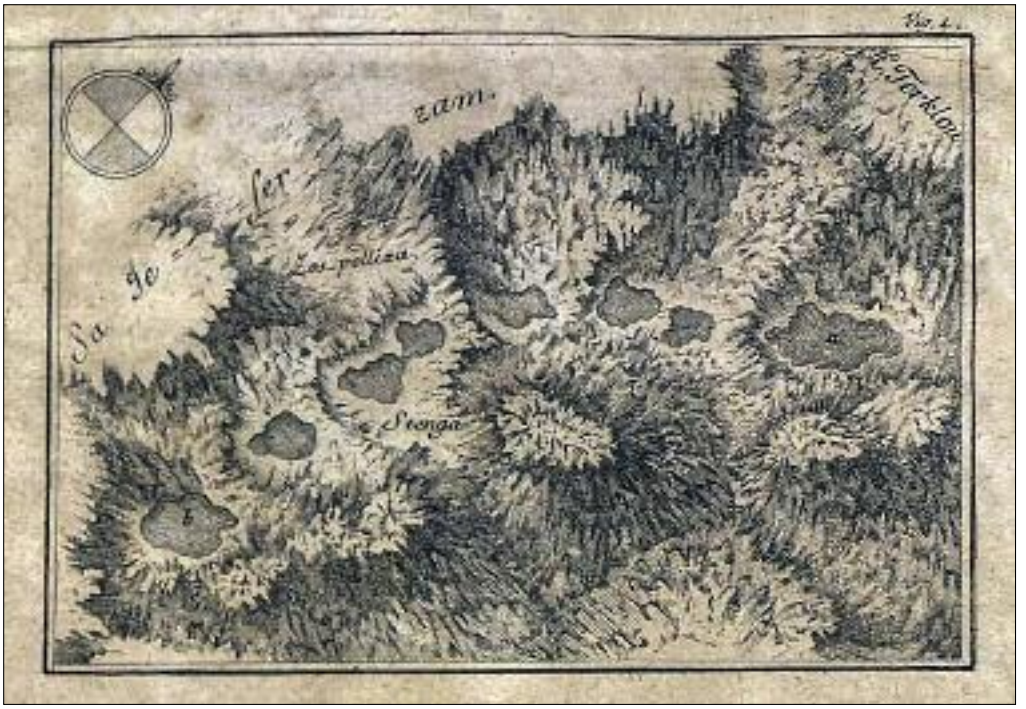

Figure 4: A map from the second half of the eighteenth century showing the Triglav Lakes Valley (Hacquet 1778).

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Figure 5: The Triglav Lakes Valley contains seven large bodies of water; the photo shows Jezero v Ledvici lake with roche moutonnée in the background.

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Figure 6: Numerous karren tables have been preserved on the glacial karst surface of Velika vrata area.

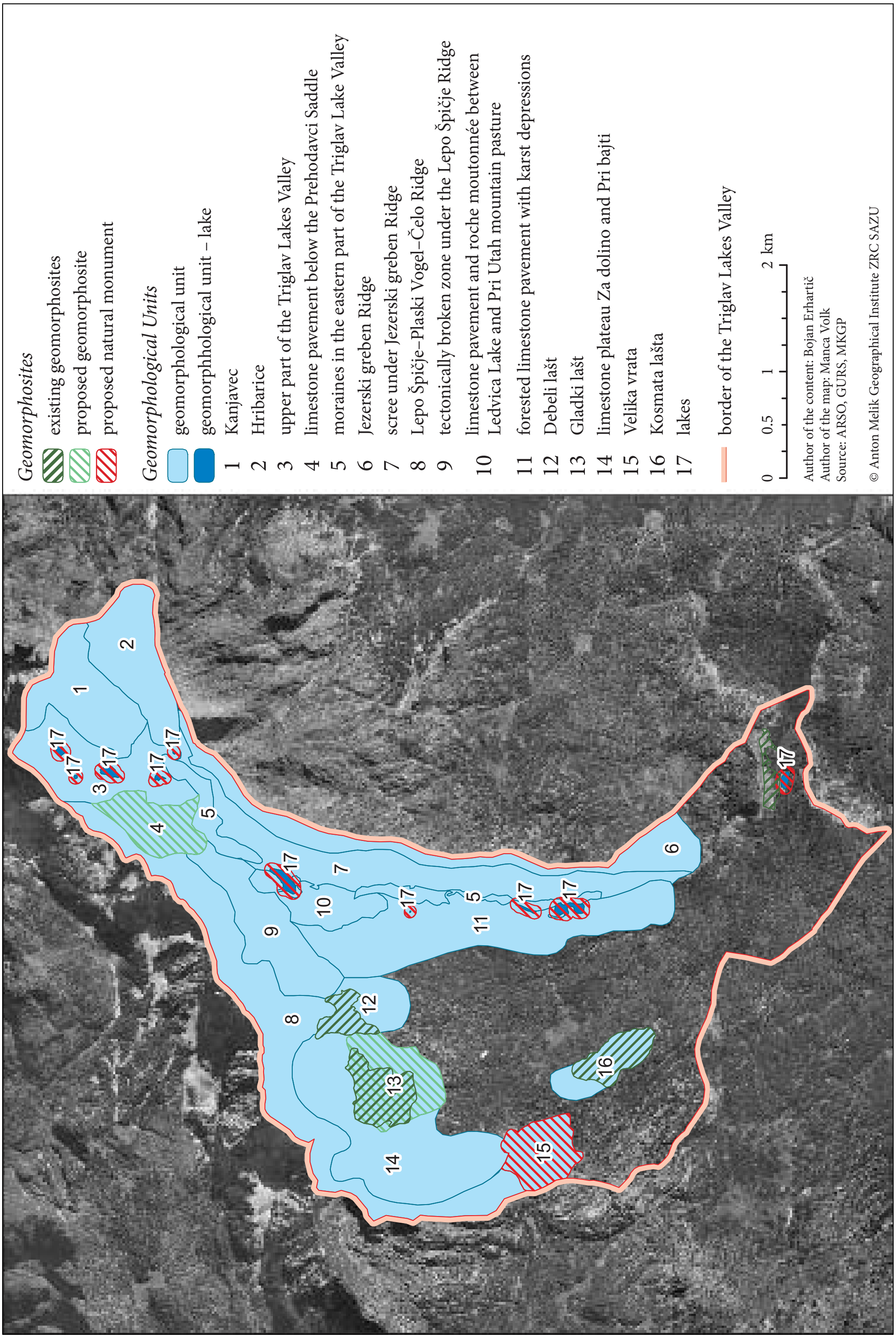
Park developed. The high mountainous Triglav Lakes Valley in the heart of the Julian Alps, which is relatively difficult to access (Figures 3 and 4), was protected in 1924. It is visited by approximately 40,000 people a year (Erhartič 2004, 69), which places a significant burden on this vulnerable high mountain karst area with its characteristic underground streams, thin soil, and modest vegetation.

The study focused on the landform analysis of the Triglav Lakes Valley and the nature-conservation evaluation of landforms. A detailed inventory of landforms was made, which included recording, analysis, and cartographic presentation of landforms. It turned out that areas with a high density and diversity of landforms had greater nature-conservation significance than individual landforms because the latter can also be in various developmental stages. Therefore, based on the relief landscape elements, the surface of the Triglav Lakes Valley was then divided into units or geomorphological complexes. A simple Swiss method (Reynard et al. 2007) was used to evaluate seventeen uniform geomorphological units. The method includes central or scientific evaluation criteria (e.g., rarity, typicality, completeness, and paleogeographical value), which are complemented by additional criteria (e.g., ecological, aesthetic, cultural, and economic value). The total value, which is the result of central and additional evaluation criteria, is provided descriptively because this preserves greater transparency of the procedure. Landform evaluation showed that the greatest geomorphological value can be ascribed to a wide variety of valley parts. However, lakes (Figure 5) and the glacial-karst surface of *Velika vrata* area (Figure 6) were evaluated as the most important nature-conservation areas. The *Velika vrata* area is important especially because of its numerous corrosion and glacial erosion forms at various developmental stages. Karren tables stand out among the glacial karst shapes because the area of *Velika vrata* is their *locus typicus* in Slovenia (Figure 6). In the high-mountain areas of the limestone Alps, lakes are important already because they are so rare and because of their ecological and aesthetic value. These are followed by the limestone pavement areas south of the Prehodavci Pass, especially thanks to its completeness and the presence of rare and typical high-mountain karst features; the roche moutonnée south of *Jezero v Ledvici* lake (Figure 5), and limestone pavement *Gladki lašt*, which is the largest limestone pavement in the Triglav Lakes Valley.

With regard to the Triglav Lakes Valley, certain discrepancies were established with the register of natural values kept by the Institute of the Republic of Slovenia for Nature Conservation and the Environmental Agency of the Republic of Slovenia; proposals for expanding the list were presented as well as (Figure 7) proposals for awarding the status of a natural value and for establishment of small protected area (natural monument):

- All the lakes are natural values, but only First Lake is recognized as a natural monument; all the lakes should acquire the status of a natural monument;
- The evaluation confirms the justification of limestone pavement *Gladki lašt* to be recognized as a natural value;
- The evaluation did not confirm the reasons for limestone pavement *Debeli lašt* to have the status of a natural value; according to the Swiss criteria, this unit does not meet the requirements to be listed among the most important natural heritage in Slovenia;
- The area of limestone pavement *Kosmata lašta* is inaccessible, so its status can neither be confirmed nor rejected;
- The geomorphologically most important area in the Triglav Lakes Valley is the area of *Velika vrata*, which has not been awarded any legal status so far; therefore we believe it should become a natural value; a further appropriate legal step in this area would be to protect it as a natural monument; – In terms of scientific value, *Velika vrata* is followed by the limestone pavement *Podi* south of the Prehodavci Pass; we also suggest that a status of natural value be ascribed to this unit;

Figure 7: Geomorphological units in the Triglav Lakes Valley and proposals for geomorphological heritage and its protection (Erhartič 2011, 139, 196). ► *str. 60*


Geomorphosites
existing geomorphosites
proposed geomorphosite
proposed natural monument
Geomorphological Units
geomorphological unit
geomorphhological unit – lake
1 Kanjavec
2 Hribarice
3 upper part of the Triglav Lakes Valley
4 limestone pavement below the Prehodavci Saddle
5 moraines in the eastern part of the Triglav Lake Valley
6 Jezerski greben Ridge
7 scree under Jezerski greben Ridge
8 Lepo Špičje–Plaski Vogel–Čelo Ridge
9 tectonically broken zone under the Lepo Špičje Ridge
10 limestone pavement and roche moutonnée between Ledvica Lake and Pri Utah mountain pasture
11 forested limestone pavement with karst depressions
12 Debeli lašt
13 Gladki lašt
14 limestone plateau Za dolino and Pri bajti
15 Velika vrata
16 Kosmata lašta
17 lakes
border of the Triglav Lakes Valley
0 0.5 1 2 km
Author of the content: Bojan Erhartič
Author of the map: Manca Volk
Source: ARSO, GURS, MKGP
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- The upper part of the Triglav Lakes Valley has a great nature-conservation value; this unit also includes five bodies of waters with natural value status. *Jezero pod Vršacem* lake is also protected as a natural monument and so it does not require an additional conservation regime;
- The area between *Jezero v Ledvici* lake and the deserted mountain pasture *Pri Utah* also stands out in terms of its value. We think that the roche moutonnée and patches of moraine material that prevent corrosion – which is extremely visible in the field – are so important that the area should be awarded the status of a natural value.

6 Conclusion

Even though the awareness of geoheritage in Slovenia is approximately as old as the country itself (Chapter 2), until a few years ago we had been lacking a problem-oriented approach to its study. However, we still too often lack the applicability of geoheritage and, nearly a decade and a half later, also geodiversity as a tool within the management of protected areas. According to Gray (2004), geodiversity is a basic principle of geoconservation and protection of places. As a term, it appears easily accessible to managers and politicians, supporting quick recognition of the need to take other aspects of conservation, in addition to biological ones, into consideration. In particular, it is felt to be useful for the conservation of abiotic heritage and the incorporation thereof in local sustainable development policies, as well as for the assessment of non-biological natural resources. From the planning point of view, the term can help integrate nature conservation into sustainable land management. This is reflected well in geoparks (Internet 4), which are actually a response by geo-science professionals to the overly strong emphasis on biological issues in the nature-conservation system. There are currently two geoparks in Slovenia: the Idrija Geopark (Peljhan, Gorjup-Kavčič, and Režun 2009) and the (Austrian-Slovenian) Karavanke/Karawanken Geopark across the border (Bedjanič, Rojs, and Fajmut Štrucl 2012; Geopark … 2012). Another one is currently being designed: the cross-border (Slovenian-Italian) Kras/Carso Geopark. In contrast to protected areas, geoparks are not defined in Slovenian legislation. Their mission lies primarily in sustainable land management with an emphasis on sustainable tourism and promotion of the area. In Slovenia, geoparks are also a relatively recent phenomenon because the first (in Idrija) was only established in 2010 (Peljhan, Stupar, and Režun 2011, 4); this is why the two geoparks already established are not yet part of the international geopark network. Establishing geoparks is definitely a step in the right direction, but nonetheless they lack not only balance between the living and non-living components of nature, but also a uniform representation of material within non-living nature because the geomorphological ones are often left in the background.

The goal of evaluating geodiversity and geoheritage (Erhartič 2011) is for Slovenia to receive a more systematic – and especially more objective – method for verifying whether specific geoheritage »deserves« to be legally protected.

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