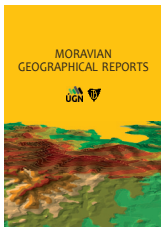

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New horizons in geodiversity and geoheritage research: Bridging science, conservation, and development

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Abstract

Geodiversity and geoheritage research has gained increasing prominence in natural and social sciences, reflecting their critical role in nature conservation, regional development, geosystem services, and environmental change. Given the inter- and transdisciplinary character of the geodiversity and geoheritage studies, a notable shift from the basic mapping, description and assessment of particular geosites to more advanced and sophisticated methods and approaches is evident during last years. Emerging research themes include quantitative analyses of geodiversity-biodiversity relationships, the dynamics of geomorphosites, innovative degradation risk assessment methodologies tailored to varying conditions, geotourism assessments in specific areas, and the application of geodiversity concepts in environmental policy and management. Additionally, integrating GIS and IT tools has enhanced the evaluation of geodiversity elements in landscape structures and ecosystem services. This article provides a brief reflection on the new directions and methods in geodiversity and geoheritage research and serves as an introduction to the Special Issue of Moravian Geographical Reports on 'Geodiversity and Geoheritage: Bridging Science, Conservation, and Development'. Generally, it can be stated that the papers included in this special issue reflect the necessity of interdisciplinary approaches to address contemporary challenges in geodiversity and geoheritage conservation and management.

Keywords: Geoheritage, risk assessment, geotourism, nature conservation

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1. Introduction

In recent decades, the research on geodiversity and geoheritage has been acquiring increasing attention within both the natural sciences and humanities. These research topics are closely linked to the nature conservation practices, geographical mapping, regional development, geosystem services, environmental change and many other issues, which make them inter- and transdisciplinary (Reynard & Brilha, 2018; Gray, 2021, 2024; Gray et al., 2023; Matthews et al., 2024).

Geographical aspects of geodiversity and geoheritage have been studied since the time of emerging of this topics, however, there is a notable shift from the basic mapping, description and assessment studies (for review, see Mucivuna et al., 2019) to more specific aspects of research and more advanced and sophisticated methods and approaches, such as e.g., risk assessment (García-Ortiz et al., 2014; Selmi et al., 2022; Kubalíková & Balková, 2023), dynamics of the geodiversity and geoheritage (Bratton et al., 2013; Bussard & Giacome, 2021; Kubalíková, 2024), geosystem services (García, 2019; Fox et al., 2020; Gray et al., 2023; Van Ree et al., 2024), spatial-temporal changes (Pál & Albert, 2021, Portal et al., 2024), links between geodiversity, geoheritage and environmental change (Pelfini & Bollati, 2014; Schrodt et al., 2019, 2024; Gordon et al., 2022; Migoń, 2024; Negri et al., 2024), the role of geodiversity and geoheritage in sustainable development (Stewart & Gill, 2017; Gupta et al., 2024; Li et al., 2024; Matthews et al., 2024) or interconnecting geodiversity, culture and cultural landscape (Gordon, 2018; Reynard & Giusti, 2018; Pijet-Migoń & Migoń, 2022; Kubalíková & Coratza, 2023). Examining the geographical aspects also allows us to analyse geodiversity in a quantitative way in relation to biodiversity and land cover, which can be used in almost all above-mentioned issues.

This article provides a brief reflection on the new directions and methods in geodiversity and geoheritage research and serves as an introduction to the Special Issue of Moravian Geographical Reports on 'Geodiversity and Geoheritage: Bridging Science, Conservation, and Development'.

2. Traditional and emerging topics in geodiversity and geoheritage research

Although the concepts of geodiversity and geoheritage have been introduced in 1990s (Gray, 2013), the proper methods for identifying, mapping or describing and assessing particular sites of Earth Science interest are much older. Originally, these methods were related to nature conservation and practical protection of particular sites (Burek & Prosser, 2008). Already in 19th century, the conservation of abiotic nature started to be done by declaring specific sites as protected (e.g., rock outcrops, specific landforms,

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caves, hydrogeological phenomena, old quarries and others). Later, systematic inventories have been elaborated (on local, regional and national level) and preliminary assessment of the sites' values have been applied.

Today, identifying, inventorying and mapping the sites of Earth Science interest represent a basic tool for further geoconservation or geotourism activities, management and development (Brilha, 2016), accompanied by various assessment methods that have been intensively developed since 2000s (Mucivuna et al., 2019). These methods are focused on scientific and added (ecological, cultural, aesthetic) values of particular sites and according to the main purposes, they are accompanied by the evaluation of the geoconservation needs, potential for geotourism development, or proposals for sustainable management of the sites. These methods are widespread and used in various conditions, very often they serve for authorities in protected areas or geoparks. In this aspect, the majority of applied methods is based on the already existing approaches or replicating the old and verified methods.

Regarding the spatial aspect, there is a shift from site-oriented research to a more complex approach. The geosite (or geodiversity site) is still in the centre of attention, but methodological approaches covering larger areas or reflecting the complexity of geosystems are developing, including quantitative methods using GIS tools (Pereira et al., 2013; Zwoliński et al., 2018; Pál & Albert, 2021) or ecosystem/geosystem services concept (Gordon & Barron, 2012; Gray, 2013; Van Ree et al., 2017, 2024; Frisk et al., 2022; Gray et al., 2023).

Despite the fast growth of scientific interest in geodiversity and geoheritage that is also reflected in the rapid increase of number of scientific papers (Kubalíková et al., 2023), there is still a number of issues that are not examined in detail. This is also caused by dynamic changes of environments and natural conditions (mostly due to environmental change), by new tasks and challenges in nature conservation and by changing attitudes of human societies on nature and use of natural resources in general. Thus, research on geoheritage and geodiversity research also reflects these aspects and address new topics and challenges. Some of the new research directions are summarised in the 2023–2027 plan of Geomorphosites Working Group (by International Association of Geomorphologists) that are primarily focused on geomorphological sites, however, they can be extrapolated to all the sites of Earth Science interest and other similar fields of studies (http://www.geomorph.org/geomorphosites-working-group/).

A vibrant topic in the geoheritage community is represented by active processes (Fig. 1). Until now, the active geomorphosites have been treated as specific and did not fit very well into the current assessment methods. However, some criteria related to active processes have been occasionally implemented in some methods (Reynard et al., 2016; Selmi et al., 2022; Kubalíková, 2024). In recent years, active geomorphosites have gained more attention as valuable geotourist and geoeducational resources with a very high geoscientific value. The paper of Bussard et al. in this Special Issue provides a comprehensive overview of the criteria that should be considered when assessing active or dynamic geomorphosites. This criteria analysis is a basis for a complex assessment method and approach that is very useful in both the scientific research and practices related to geoconservation and geotourism.

Other directions in the current geodiversity and especially geoheritage studies are represented by examining the close relationships between geoheritage and tourist use. Numerous assessment methods have been developed for assessing geosites and geomorphosites from the geotourist potential point of view (for an overview, see Štrba et al., 2023). These methods have been usually adapted to particular areas and specific – regional and/or local conditions, including mountain areas (Carrión-Mero et al., 2021; Bollati et al., 2023), coastal areas (Selmi et al., 2022; Morante-Carballo et al., 2023), urban areas (Kubalíková et al., 2021; Vegas & Diez-Herrero, 2021) or arid areas (Sayama, 2024). Very specific areas are represented by greatly vulnerable karst areas, but they are important as tourist destinations, thus very frequently visited and intensively used. In this Special Issue, Antić et al. developed a complex method for assessing the tourist potential of karst caves and apply it to selected caves in Switzerland. The added value of this method is in the inclusion of public preferences and expert evaluation.

As geodiversity and geoheritage are continuously at risk and endangered by numerous threats (Fig. 2), the risk assessment methods and approaches are also gaining more attention: risk assessment is a part of common geosite or geomorphosite methods (Brilha, 2016); however, in recent years, the methods focused directly on threat assessment and risks have been developed (García-Ortiz et al., 2014; Selmi et al., 2022; Kubalíková & Balková, 2023; Vandelli et al., 2024). The risk assessment may differ according to the spatial context (e.g., urban areas, rural areas, coastal or mountain areas), and the character of particular threats also varies (Crofts et al., 2020; Anougmar et al., 2024); thus, the proposed parameters may differ, even though generally, the basic set of criteria used

Fig. 1: The influence of active geomorphological processes on geoheritage is twofold: on the one hand, they may lead to the degradation of Earth Science phenomena (e.g., erosion may cause the destruction of stratigraphic profile), on the other hand, active processes represent an inseparable element of the geoheritage sites themselves and possess and important scientific value. Rudice-Seč abandoned sandpit (left) and Osypané břehy (right), both situated in South-Eastern Moravia, Czech Republic, and protected as Nature Monuments, are the examples of the sites where natural processes such as fluvial erosion and slope processes represent an integral part of the wider area
Photos: L. Kubalíková

Fig. 2: Threats to geoheritage may be represented e.g., by overtourism. The outcropping flysch sedimentary rocks in Zumaia (Basque Coast Geopark, Spain) are situated just on the beach which is intensively used by tourists. Photo: L. Kubalíková

for the risk assessment (degradation risk assessment) remain the same. Anyway, apart from the classical assessment of degradation risk (as reviewed by Vandelli et al., 2024) and eventually SWOT analysis which also contains the identification and analysis of threats (Kubalíková & Kirchner, 2016; Carrión et al., 2018), there are other approaches, represented for example by multicriterial analysis (Ahmadi et al., 2022) or application of risk assessment matrices (Brooks, 2013; Kubalíková & Balková, 2023). The use of these methods is quite common in projects or regional development management, but their use in geodiversity and geoheritage studies has not been so widespread. In this Special Issue, a paper by Kubalíková et al. reflects these issues. It applies a methodological approach for assessing risks and threats in a rural area that may be endangered by overtourism. It also discusses the possibilities of nature conservation that may be useful, but sometimes, they do not meet the needs of a particular site.

A huge emphasis is placed on quantitative methods using advanced computing and GIS tools (Pereira et al., 2013; Zwolinski et al., 2018; Najwer et al., 2022; Zakharovskyi et al., 2023; Pál & Albert, 2023). Initially, this field of research was focused on mapping and GIS analyses and based on that, the sites or areas of high geodiversity have been selected, e.g., to be protected or used for geotourism development (Santos et al., 2017; Rypl et al., 2020; Chrobak et al., 2021; Barančoková et al., 2023). These studies responded on many questions concerning mutual relationships between morphology, lithology and hydrological elements. They have enabled to illustrate how geodiversity influences biodiversity or species richness (Tukiainen et al., 2017, 2023; Crisp et al., 2023; Alahuhta et al., 2024; Toivanen, 2024). Studies dedicated to the mutual relationships between geodiversity elements and landscape structure are relatively sparse but have developed in the last few years (Pătru-Stupariu et al., 2017; Datta, 2022). In this Special Issue, this methodological approach is represented by the paper of Albert and Kraja, who examine the links between geodiversity elements and their influence on landscape structure exemplified on a study area in Albania.

3. Bridging nature, science and society

As previously emphasised, the research on geodiversity and geoheritage is highly inter- and transdisciplinary, especially in the last years when developing new methods that enable understanding complex relationships between nature and human society. In many aspects, it also helps to frame the nature conservation activities and sustainable use of the landscape and natural resources. Geodiversity and geoheritage are also reflected in and represent a significant contribution to all the Sustainable Development Goals (Stewart & Gill, 2017; Matthews et al., 2024) that confirms their importance and relevance. All the papers included in this Special Issue also possess these issues and contribute significantly to bridging nature, science and society in many aspects.

The paper of Jonathan Bussard, Andrea Ferrando and Aleksandar Antić focuses on the evaluation of active processes on geomorphosites. Based on a detailed analysis, they present a new approach that may serve not only for scientific assessment of geomorphosites in dynamic zones, but it is also useful in geoconservation management. Through three case studies in the Swiss Alps, their results show that an ideal management practice would be to maintain the natural dynamics and rate of change of geomorphological processes, with exceptions when they have a negative impact on landforms of higher heritage value than the processes, or when they threaten human life or infrastructure. Thus, their method is of high relevance both for preserving natural processes and contributing to quality of life of people residing in specific areas.

Aleksandar Antić, Marc Luetscher, Amandine Perret, Andrea Ferrando and Emmanuel Reynard developed a complex method for assessing the tourist potential of karst caves and apply it to selected caves in Switzerland. Given the fact that show caves are considered a very fragile environments and they are of high geotourism relevance, a need for finding a balanced method for assessing these extraordinary sites of Earth Science interest is very urgent and evident. Combining quantitative and qualitative analyses, including geological, ecological, and cultural factors, their paper offers a comprehensive assessment approach, contributing to a practical methodology for cave management, as well as cave tourism planning with regards to the conservation needs. The study provides insights beyond academia, guiding stakeholders involved in cave tourism development, and striving to balance ecosystem preservation with sustainable economic growth.

The paper by Lucie Kubalíková, Karel Kirchner and Piotr Migoń is focused on new, emerging aspect in geoheritage studies – the evaluation of risks and threats. The application of semi-quantitative assessment methods (degradation risk evaluation and Risk Assessment Matrix) in the Chřiby Mountains (a rural area in Czech Republic that may be endangered by overtourism due to the presence of numerous sandstone crags with high geoheritage values) enabled the ranking of the sites according to the degree of possible deterioration and helped to identify particular threats, which can be considered important when planning and managing the area's natural resources. The recognition of geoheritage values of sandstone crags, along with identifying and evaluating risks and threats, may serve as a basis for effective management and further research. The paper also discusses the possibilities of nature conservation (geoconservation) that may be useful, but sometimes, they do not meet the needs of a particular site and need to be discussed with local stakeholders.

Gáspár Albert and Drisela Kraja examine the links between geodiversity elements and their influence on landscape structure exemplified on a study area in Albania. Using open-source GIS tools, they analyse the diverse geographical features, including coastal, agricultural, urban, riverside, and mountain terrains. Their analyses, conducted at low, medium, and high altitudes, reveal a positive correlation between geodiversity and land cover diversity in lower regions but a negative correlation in higher elevations. The results highlight the importance of taking geodiversity into account in conservation efforts and can provide important support for impact studies to be carried out in the planning phase. Their study can be also considered a basis for identifying potential geotourism hotspots characterised by high geodiversity and to estimate the potential impact of tourism activities on local natural values, considering land cover diversity and connectivity.

Despite its limited extent, this Special Issue shows a diverse range of topics in geodiversity and geoheritage research, introducing new perspectives on well-established research areas and methodological approaches. The published papers illustrate emerging trends and pave the way for future research directions in this area.

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