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Geodiversity beyond material evidence: a Geosite Type based interpretation of geological heritage

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ABSTRACT

Geosites can be organized in Geosite Types based on genetic, compositional and structural characteristics, with each Geosite Type (e.g. geomorphological, paleogeographical, structural) being defined and identified by a corresponding feature or set of features as evidence of geological processes. This evidence must be accessible and well-conserved for a Type to be considered interpretable and must be meaningful and suitable for wider correlations for a geosite to be considered an expressive example of a particular Type. The quantitative assessment of geodiversity provides a general overview of an area's potential heritage for research and education by measuring the number of geosites, Geosite Types, geosites per Geosite Type and geodiversity *loci* (i.e. areas with high concentrations of geosites). The qualitative assessment considers each geosite as actual heritage. The Interpretation Score (IS) establishes how accessible and meaningful in situ geological evidence is and whether wider geological connections are possible. The Heritage Value (HV) measures how common or unique geosites are in a particular area. The Bucegi Natural Park in Romania's Southern Carpathians hosts a high number of geosites, but proper use of geological resources is overshadowed by economic interests. Some geological heritage sites hold valuable evidence of pre-glacial conditions and glacial stages having occurred on both a local and regional scale. These geosites could be successfully used for geotourism purposes and could help increase knowledge and appreciation of the park's geological history among national and international visitors.

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1. Introduction

Geodiversity has emerged as a topic of international interest in the last decades of the 20th century. The first concerns regarding geological and geomorphological diversity were crystallized in the late 1980s by K. Kiernan (Gray, 2004, 2008a, 2013), while the first usage of the concept in a strict geological meaning dates back to the early 1990s and is attributed to both C. Sharples and F.W. Wiedenbein (Gray, 2008a). The first definition (Sharples, 1995) was subsequently adopted and expanded (Johansson, 2000; Stanley, 2000) and geodiversity is now commonly regarded as the "natural range of geological (rocks, minerals, fossils), geomorphological (landforms, processes) and soil features, including their assemblages, relationships, properties, interpretations and systems" (Gray, 2004, p. 8). Earlier recordings of the word *geodiversidades* can be found in the works of F.A. Daus, who defined it as a diversity of cultures within a given region (Serrano and Ruiz-Flaño, 2007). While such a concept would be useful nowadays in a world of increasing globalization and homogenization, this original, geographical, meaning of geodiversity has been widely overshadowed by its more recent, geological, meaning.

Geodiversity has been a recurring subject of interest in literature over the last decades, with much work conducted so far in both philosophy and practice (Kiernan, 2001; Sharples, 2002; Kozłowski, 2004; Gray, 2004, 2008a,b; Gordon and Barron, 2010, 2011; Blue and Brierley, 2012). The first book on geodiversity (Gray, 2004, 2013) offers a comprehensive view on what geological heritage is, why it must be valued and how it can be managed. Tourism based on geology and geomorphology (geotourism), which is both recreational and educational in nature, emerged as a small niche, but is now rapidly expanding and becoming a world industry (Hose, 1995, 2000, 2005, 2008, 2012; Dowling and Newsome, 2006; Dowling, 2010; Newsome and Dowling, 2010). The global distribution and growing research interest for this area have been recently documented (Ruban, 2015). Geoeducation defines a key part of education for nature conservation addressed to a wide public, although it still needs to consolidate and broaden its framework and develop its own educational tools (Andrăşanu,

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2006, 2009). Geoconservation has a rich history of practice, especially in northwestern Europe, Australia and the US (Brilha, 2002; Sharples, 2002; Burek and Prosser, 2008; Erikstad, 2008; Thomas and Warren, 2008). This new domain, which is slowly becoming a science of its own (Brilha, 2011; Henriques et al., 2011), has a scientific and a social dimension and focuses not only on enhancing geological diversity and conserving endangered sites, but also on raising awareness among local communities and international organizations on its vital, but still underestimated, role in nature conservation (Prosser et al., 2011, 2013; Prosser, 2013). Focus has also been placed on geoparks as specially designated areas where conservation of universally valuable geological heritage becomes intertwined with the development of local communities (Eder and Patzak, 2004; Zouros, 2004). The sustainable use of geological resources, whose diverse utilitarian value provides a wide range of geosystem services, requires ongoing research and proper land management (Gray, 2005, 2011, 2012). The quantitative and qualitative assessment of geodiversity and geological heritage became a paramount priority in many countries and serves different purposes, such as sustainable development and conservation of protected areas (Serrano and González-Trueba, 2005; Pereira et al., 2007), remote sensing identification (Seijmonsbergen et al., 2009), regional surveys (Reynard, 2006; Reynard et al., 2007; Pereira and Pereira, 2010), proper use, management and promotion (Bruschi and Cendrero, 2005; Pralong, 2005; Zouros, 2005, 2007) of relevant geological and geomorphological sites, or more generally, land-use planning (Coratza and Giusti, 2005) and large-scale geodiversity studies (Pereira et al., 2013).

Most assessment methods and processes consider geodiversity as physical phenomena and features that are actively being surveyed and mapped. However, when conservation and interpretation of geological heritage are an overriding goal, geodiversity can be regarded as both *matter* and *knowledge*. Geosite Types, established according to the genetic, compositional and structural characteristics of geosites, are a useful indicator of the scientific and educational information that can be collected for purposes such as research, studying or recreational activities (Ruban, 2010; Ruban and Kuo, 2010).

This paper provides a quantitative and qualitative assessment of geodiversity seen as potential and actual heritage. The quantitative assessment draws some general parallels with biodiversity and provides an overview of an area's potential heritage for geotourism. The qualitative assessment focuses on actual heritage and depends on each Geosite Type being linked with a well-defined in situ material expression. The Interpretation Score (IS) of geosites reflects the accessibility and quality of geological evidence specific of each Geosite Type. The Heritage Value (HV) measures the relevance of geosites at a scale corresponding with the size of the study area. Both quantitative and qualitative analyses are supported with examples of geosites located in the Bucegi Natural Park of Romania's Southern Carpathians.

2. Theoretical considerations

Understanding the diversity of nature is necessary for all fields of science. Fundamental heuristic schemes, also known as ordering systems and processes, are commonly used for a wide range of animate and inanimate objects, especially in biology (Mayr and Bock, 2002) and geology (Bradbury, 2014). For the same reason why a system of chronological measurement is needed to provide a comprehensible view of the exceptional extent of the Earth's history, creating an adequate Geosite Typology is needed for a better understanding of the geological features and phenomena that are later to be explained and interpreted. This step may even precede the identification of geosites (García Cortés et al., 2000; Gonggrijp, 2000). Without ordering systems, diversity in general would be hard to encompass and even less so to understand and quantify.

Geological heritage sites, commonly referred to as geosites, are represented by a wide range of "exposed geological objects or fragments of the geological environment" (Ruban, 2010, p. 326). Their main attributes – visibility and accessibility – enable them to be visited and studied. Geodiversity features that "cannot be seen (observed, touched, probed) by visitors" (cf. Ruban, 2005, in Ruban, 2011, p. 512) or those located in remote areas where access is restricted or prohibited cannot be used for educational purposes, although their intrinsic qualities and functional role remain unaffected. A brief distinction can therefore be made between *geotopes*, where focus is placed on ecosystem function and integration and where the interest for scientific research and engineering applications prevails over the interest for geotourism, education and economic use, which is more common for *geosites*.

Twenty-one Geosite Types were identified based on origin and characteristics of sites: cosmogenic, economic, engineering, geochemical, geocryological, geohistorical, geomorphological, geothermal, hydrological and hydrogeological, igneous, metamorphic, mineralogical, neotectonical, paleogeographical, paleontological, pedological, radiogeological, sedimentary, seismical, stratigraphical and structural (Ruban, 2005, 2010; Ruban and Kuo, 2010). This ordering was preceded by an earlier geographical approach according to which the number of Geotope Types equals the number of disciplines and sub-disciplines within the Earth Sciences (Grandgirard, 1999), hereby showing the directions in which geological heritage can be studied, but also interpreted and promoted (Wimbledon et al., 2000). The economic, engineering and geohistorical Types are related to human intervention, while the rest of the Types are commonly identified in nature regardless of human intervention. The human-related Types may be beneficial or neutral in effect, but also potentially or effectively harmful. The engineering Type may be represented by a dam or anthropic structure that helps stabilize slopes or forestall landslides, so the integrity of a geosite can be maintained. The geohistorical Type may be represented by ancient cave dwellings or archaeological sites that show the geological-scale, but not necessarily negative, influence of early humans on geological diversity (Gontareva et al., 2015; Moroni et al., 2015). The economic Type may be represented by large-scale quarrying, which can cause loss of valuable fossils.

Unlike more recent classifications of geodiversity, which are genetic in nature and overarching in purpose (Bradbury, 2014), the Geosite Typology developed by Ruban (2010) and Ruban and Kuo (2010) is suitable for a manifold interpretation of geological heritage by means of inference, observation and connections between several aspects of geodiversity, such as origin, composition and structure. The information collected from geosites is crucial in recreating an event or a sequence of events in the geologic history of Earth. Simple geosites fall within a single Type. For example, an outcrop of columnar basalt as an igneous geosite falls within the igneous Type. Complex geosites fall within several Types. If localized evidence of glacial polish is visible on an outcrop of columnar basalt, the geosite has both igneous and paleogeographical relevance and falls within the igneous and paleogeographical Types. Both Types reflect the different processes that shaped the geosite: endogenous processes represented by past effusive eruptions of basaltic lava and exogenous processes represented by more recent glacial polishing. In a similar way, an exposed cliff face is often a complex geosite, whose relevance can be simultaneously geomorphological, paleontological, sedimentary, stratigraphical, structural, etc. (Fig. 1). Some combinations of Geosite Types given by complementary geological features

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