

Inventory and Quantitative Assessment of Geosites and Geodiversity Sites: a Review

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Abstract The inventory and quantitative assessment of the most valuable occurrences of geodiversity are essential steps in any geoconservation strategy and in the establishment of priorities in site management. Despite the existence of many site inventories applied to different scales (countries, municipalities, parks, etc.), the criteria used for their selection are often unclear and poorly defined. This paper proposes a new approach to the concepts of geosite and geodiversity site and reviews the procedures used in the development of a systematic site inventory applied to different scales and values. Procedures to achieve a numerical evaluation of the value and degradation risk of sites are reviewed and new criteria are proposed. Finally, guidelines are presented, bearing in mind the preparation of effective geodiversity inventories, to support geoparks' strategies. This paper aims to contribute to a better understanding and use of the above-mentioned concepts, which are essential for the implementation of geoconservation actions worldwide.

Keywords Geosite · Geoheritage · Geodiversity site · Geopark · Inventory · Geodiversity

intention to discuss these concepts in detail. However, it is necessary to propose a systematic approach given that

be emphasised that the economic value associated with the exploitation of geological resources is not considered under the scope of geoconservation.

In a certain way, mining heritage is also related to geoheritage and geodiversity. Usually, the term 'mining heritage' applies to whatever is involved in active and inactive mining exploration, such as minerals and rocks that are being (or were) extracted, industrial facilities, historical documentation of old mines, exploitation processes and techniques, and even mining communities' stories and traditions. If mineral and rock occurrences are still available and have scientific value, they should be considered geoheritage (mineralogical or petrological heritage). Sometimes, these occurrences only have educational and/or touristic value and, if this is the case, they

Inventory of Geosites

The present proposal for obtaining a systematic and solid inven-

ProGEO—The European Association for the Conservation of the Geological Heritage (Erikstad 2008; Wimbledon 2011 and references therein). The geological frameworks of a territory are the main themes related to geoscience materials and/or processes that allow a better understanding of the geological history of that same territory. Geological

conditions can be distinctly different if a site is to be used by young children or by university students.

all sites, which does not contribute to the required site discrimination. For instance, population density (a criterion, used to assess the PEU) has the same value for all sites if a small area is being studied. Hence, for very small areas with very few sites, there is no need to do a quantitative assessment of the value/use of sites.

Even if a number comes out as the final result of a quantitative assessment, this does not mean that it is not necessary to proceed with a critical and detailed analysis of the results. Sometimes, the final result may place a certain site at the bottom of the list but the inventory coordinator intuitively knows that the same site is significant in the area. These kinds of contradictions need to be explained and interpreted. The scientific coordinator of the whole process should have the final and definitive word about the sorted list of sites for the area under consideration.

As stated before, the present methodological proposal for the quantitative assessment of geosites is the result of a survey and compilation of the best published practices (see previous references in this section) and the author's own experience.

Quantitative Assessment of Scientific Value

For the quantitative assessment of the SV of geosites, seven criteria can be used:

A. Representativeness: capacity of a geosite to illustrate

Table 3 Criteria, indicators, and parameters used for the q

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- ✓. Density of population—the existence of a population near the site, potentially providing students who will use the site, increases its EV
 - . Association with other values—the existence of other natural or cultural elements associated with the site may justify interdisciplinary fieldtrips and increase the EV of the site
 - . Scenery—represents the beauty of the geological elements that could stimulate students' interest for the site and thus increases its EV
 - ✓. Uniqueness—concerns the distinctiveness and the rarity of the geodiversity element that could promote students' interest for the site and raise its EV
 - . Observation conditions—the better the conditions for observation of all the geodiversity elements on the site, the higher its EV
 - . Didactic potential—the use of the site by students of different education levels increases the EV of the site
 - . Geological diversity—a high number of different geological elements with didactic potential increases the EV of the site.

measures its degradation risk under present natural conditions, i.e., without the intervention of Man. A site is fragile when a process of either a rapid (human scale) damage or destruction occurs'. Both concepts are used with the same meaning in the present work.

The proposal for the quantitative assessment of site DR was developed taking into consideration the author's experience and the best practices published in recent years, including Cendrero (1996a; b), Brilha (2005), Carcavilla et al. (2007), Reynard et al. (2007), García-Cortés and Carcavilla Urquí

Table 5 Criteria, indicators, and parameters used for the quantitative assessment of the potential educational and touristic uses. Ten criteria (A–J) are shared between these two types of uses. Two more criteria (K–L) are used to assess PEU and three (K–M) for PTU

Criteria/indicators	POTENTIAL EDUCATIONAL AND TOURISTIC USES	Parameters
A.	The geological elements of the geosite present no possible deterioration by anthropic activity	4 points
	There is the possibility of deterioration of secondary geological elements by anthropic activity.	2.6(e)0(d)1.98(u)0(c)23(a)0(t)1.36(i)15.0000020075840158m.n of sec a

(2009), Lima et al. (2010), Pereira and Pereira (2010), and Fassoulas et al. (2012).

As before, each criterion is scored between 1 and 4 points (zero is also possible) (Table 7). The final DR value results from the weighted sum of the scores given to each criterion (Table 8). For management purposes, it might be useful to have the DR classified as low, moderate, and high (Table 9).

It is worth mentioning that criteria D (accessibility) and E (density of population) are used both in the evaluation of the educational and touristic value of sites and the DR. However, these criteria are considered in a different manner. To assess

the value of a site, good accessibility is considered an advantage because it allows a higher number of visitors. A high number of persons living near a site are also considered an advantage for potential educational and touristic use. However, good accessibility to a site is also a risk in terms of vulnerability because the more people that visit the site, the

Geodiversity Inventory in Geoparks

Geoparks are becoming quite popular in certain regions of the world. Geoparks are well-defined territories with a development plan that aims to integrate the conservation of geological heritage (and other natural assets) with the preservation of the cultural identity of local communities. Based on the conservation of natural and cultural assets and on the promotion of education and geotourism, geoparks are tools designed to promote the sustainable development of local populations (Patzak and Eder 1998; Eder 1999; Eder and Patzak 2004; Zouros 2004; McKeever et al. 2010). A Global Network of National Geoparks (GGN), set up under the auspices of UNESCO in 2004, today integrates 111 geoparks distributed in 32 countries, mostly in Europe and Asia. In order to be accepted in this network, candidate territories must apply and show that they fulfil a rather complete set of requirements. One of these requirements is the inventory of geological heritage, a key asset of any geopark.

different values but it is given diverse weights in the final evaluation.

Finally, the assessment of the degradation risk uses five criteria: deterioration of geological elements, proximity to areas/activities with the potential to cause degradation, legal protection, accessibility, and population density.

One of the main differences of the assessment proposal presented here in comparison to the majority of published

- Eder W (1999) "UNESCO GEOPARKS"—a new initiative for protection and sustainable development of the Earth's heritage. *N Jb Geol Paläont (Abh)* 214(1/2):353–358
- Eder W, Patzak M (2004) Geoparks—geological attractions: a tool for