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Geodiversity and geoheritage in the perspective of geography

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Abstract. The paper states that geodiversity is the abiotic complement to biodiversity, and is considered to be the elements associated with the abiotic environment, e.g. geological diversity, geomorphodiversity, pedodiversity, hydrodiversity and climodiversity. Geoheritage is considered as the geological heritage of a site, but is here presented as the abiotic heritage of a site, and is related to geological heritage, geomorphoheritage, pedoheritage, hydroheritage and climoheritage. Thus, it is possible to talk about geological sites, geomorphosites, pedosites, hydrosites and climosites. Geodiversity and geoheritage are strongly linked to geology. However, it is also a new paradigm to geography, as physical geography classically works with abiotic and biotic environments.

Key words:
Geodiversity,
Geoheritage,
Geosite,
Geological,
Paradigm,
Geographical,
Paradigm

Introduction

The concept of natural diversity can be divided into biotic and abiotic elements (Boothroyd and McHenry 2019). It can be said that geodiversity, a term widely used in the field of geoconservation, especially in the last two decades, was forged (Sharples 1993; Wiedenbien 1994) to be the abiotic complement to biodiversity.

Presently, there is no clear and universally accepted concept of geodiversity (Boothroyd and McHenry 2019; Ibáñez and Brevik 2019). One of the most accepted definitions of geodiversity among geoscientists was offered by Gray (2004), who considered geodiversity as the variety of geological (rocks, minerals, fossils), geomorphological (landscapes, geomorphic processes) and soil elements of an area, including their assemblies, relationships, properties, interpretations and systems. Later, Gray (2013) included hydrological elements in the main body of this concept. Taking into account Gray's concept of geodiversity (Gray 2013), it can be considered that geodiversity should be related to all diversities of the abiotic environment, such as geological diversity (Gray 2004, 2013), geomorphodiversity (Panizza 2009; Zwoliński 2009; Kot and Leśniak 2017; Kot 2018), pedodiversity (Ibáñez et al. 2013), hydrodiversity (Gray 2013) and climodiversity (Phillips 1999).

Nevertheless, in practice, most geodiversity experts have ignored most of the aspects of the abiotic environment to concentrate on the geological diversity of sites. If one considers that geology studies the structure, evolution and dynamics of the

Earth and its natural mineral and energy resources (Royal Geographical Society 2020), it is evident that the scientific production on geodiversity has been restricted to one small part of abiotic nature. Nevertheless, the practice of experts should include not only geological elements and processes, as has mostly happened in the scientific production related to the theme, but all the abiotic richness of the environment. Following this reasoning, the concept of geodiversity can be presented: it represents the variety of elements and processes associated with the abiotic environment – geological diversity, geomorphodiversity, pedodiversity, hydrodiversity, climodiversity – in any forms, spatial and temporal scales and modes of interaction. A simple scheme represents the liaisons among these features (Fig. 1).

Geodiversity, moreover, is considered to be constituted by the Earth's framework that sustains life, being the result of the Earth's slow evolution since its emergence. This means that geodiversity is associated with the physical environment, consisting of a range of phenomena and processes that give rise to rocks, mineral, landscapes, topography, climates, waters, soils, fossils and deposits that favour the development of life on Earth. In this way, the concept proposes to dialogue directly with the lay public in order to inform them that just as important as knowing the diversity of biotic elements on the planet (biodiversity) is knowing where all living beings live, reproduce and develop. It seems effectively necessary to open more widely the definitions of geodiversity to embrace all the abiotic diversity, with the goal of allowing greater scientific production on the subject and promoting the participation of professionals other than geologists in the process, in the perspective of the conservation of abiotic and biotic nature.

Geoheritage, on the other hand, means the geological heritage of a site. The Geological Society of America, for example, and most of the literature on the subject, attests that geoheritage is a generic but descriptive term applied to areas or sites that have geological features of significant scientific, educational, cultural or aesthetic value (Geological Society of America 2012). From an abiotic point of view, this definition is too restrictive. It is understandable that "geological features" could, at the extreme bounds of the concept, be understood as all abiotic elements, but this does not follow the logic of modern sciences and modern facts: since objects are very well defined in all branches of Earth Sciences, why should the same not also be the case in geodiversity and geoheritage?

In this sense, it should be considered, as an alternative definition, that geoheritage is related to geological heritage, geomorphoheritage, (Panizza 2001), pedoheritage (Conway 2010; Ibáñez et al. 2013), hydroheritage (Seymour 1992) and climoheritage, representing the ensemble of abiotic elements that have high values to society from a scientific, educational, cultural or aesthetic point of view, in all their combinations of processes, forms and scales.

The term "hydroheritage" has been used as "hydro heritage" by Seymour (1992), in the sense of anthropogenic heritage (such as dams). That author does not give it the same meaning as the one here, considering that the idea of geoheritage used in this paper is that of abiotic elements. Nevertheless, the name "hydroheritage" was taken (adapted from "hydro heritage" to "hydroheritage"), to represent important natural hydrosystems, elements or processes that have high value to society, such as springs in dry areas, important fluvial captures, and exceptional tides or currents, among others.

In relation to climoheritage, which seems not to have been considered by the literature, it can be said that it is a natural intangible heritage, whose possible features include, for example, cold climates within hot regions (as seen in mountainous areas of the tropics), or the presence of dew in desert environments. In the first example, it is considered

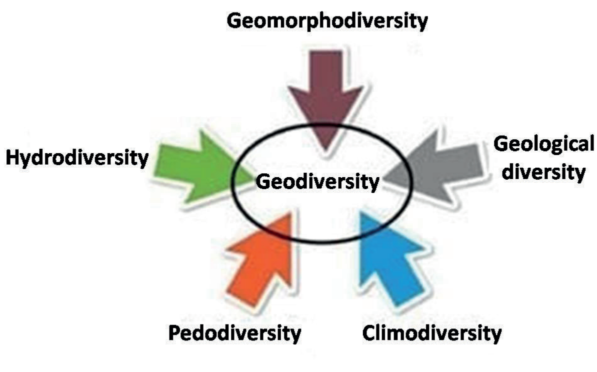

Fig. 1. Geodiversity and its integrated components

that cold weather creates climates of exception in hot tropical regions, resulting in a completely different way of life, economic exploitation, and specific characteristics of the other elements of the biotic environment where they exist, and that these differences have a high scientific, cultural and economic importance. In the second example, it could be considered that dew is at times the only source of water to the biota, and is thus of great importance to the environment, and of great value as a scientific heritage. Other examples could be presented, such as the action of the trade winds promoting coastal dynamics as they create waves and push longshore currents (which transport sediments), with a great importance in the economy (sports, aeolian energy).

The definition of geoheritage in these terms seems to open more possibilities of including within the core of the concept many aspects that otherwise could be missed and lost if it continues to be seen only in the perspective of “geological features”. Here, the goal is to amplify the scope of geoheritage studies to promote a better conservation of all the elements that contribute to creating special features in the abiotic environment and thereby to strengthening the conservation of biodiversity.

After these considerations, it is important to inform, or reinforce, that the present paper aims to discuss, in a synthetic way, geodiversity and geoheritage from a geographical perspective. The article does not intend to be an empirical study, nor to exhaust the subject. On the contrary, it is actually a first approach to these topics, aiming to launch ideas for debate and future discussions. In this sense, it is an exercise in initial reflections, which are presented in the following items.

Geodiversity and (some) approaches of Physical Geography

Geodiversity and geosystem

The Geosystem Theory was formulated to apply the General Systems Theory of Bertalanffy (1968). According to Sotchava (1962, 1977), a geosystem is a dimension of terrestrial space where different natural components are connected, presenting a defined integrity, interacting with the cosmic sphere and with human society. Bertrand (1971) considered the geosystem as a spatial category of relatively homogeneous components whose dynamics result from the interaction between ecological potential, biological exploration and anthropic action.

It is not the objective of this paper to discuss concepts of geosystems. But, departing from these mostly known definitions of the term, it can be said that geodiversity and geosystem are both paradigms that deal with natural environment. Nevertheless, the geosystem, unlike geodiversity, contains biotic elements, as they also include ecological potential (fauna and flora). In addition, the geosystem integrates anthropic action or society, which is not the case with most concepts of geodiversity, including the one presented here.

In this comparison, another aspect can be seen: geosystem has no time scale, whereas geodiversity embraces processes and, in this sense, analyses the genetic and evolutionary aspects of the abiotic elements of nature over time. It is also worth noting that, in a general point of view, the geosystem has been used to denounce and point out the degree of degradation of the biotic and abiotic dimensions of nature (e.g. Kharin 1994; Garcia-Romero 2002; Chendev et al. 2008; Solodyankina et al. 2018) while geodiversity contains the notion of conservation, being closely related to the idea of geoconservation (e.g. Ibáñez et al. 2019).

Related to this aspect of geoconservation, Gray (2011) testifies that most published works on ecosystem services (considered here as “the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life”: Daily 1977, p. 3) refer mainly to biotic services. But, just as geodiversity is the abiotic equivalent of biodiversity, so geosystem services can be recognised as the goods and functions associated with geodiversity (Gray 2008, 2011), which strongly relates to the ability of the studies on geodiversity to produce geoconservation, as wells as other functions and goods for humankind.

Some authors (e.g. Giusti and Calvet 2010; Giusti et al. 2013; Rabelo et al. 2019) have considered the relationship between geodiversity and geosystem approaching spatial scales (geomorphosites framed as geotope, geofaces, geosystem). Nevertheless, they did take into consideration the idiosyncrasy and incongruences of working conjointly with both paradigms, e.g. the paradigm that highlights biotic and anthropogenic dimensions (geosystems) and the paradigm that works with abiotic nature, as is the case for the most accepted concepts of geodiversity (on the importance of cultural elements in the geodiversity concept, see "Geodiversity and landscape" below.

In light of the differences mentioned above, it seems that, even considering that geosystem and geodiversity both work with physical environment, it does not seem possible to develop both approaches in the same perspective. They are mostly complementary, or specific, and could not be used alongside one another in a single analysis of the same subject. It has already been suggested that inconsistencies in interpretations and usages are preventing geodiversity from becoming a fully operationalised concept (Boothroyd and McHenry 2019; Ibáñez et al. 2019).

Geodiversity and landscape

For a long time, geographers accepted that landscape meant the portion of the geographical space taken in by the eye. In Bertrand's (1971) point of view, landscape is a certain portion of space that represents the result of the dynamic combination of physical, biological and anthropic elements, which reacting dialectically make it a unique and inseparable set, in perpetual evolution. Also, the American geographer Sauer (1925), representative of classical cultural geography, points out that this interaction between natural and anthropic elements is essential in understanding landscape. Ab'Saber (2001) considered that landscape is a heritage of physiographic and biological processes that represent a collective heritage of the people who historically inherited it as the territory of their common activities. Claval (1999), in turn, attributes to man the responsibility of transforming the landscape. The European Landscape Convention (2000), finally, testifies that the landscape is part of the land, as perceived by local people or visitors, and evolves through time as a result of being acted upon by natural forces and human beings.

It is not the purpose of this paper to exhaustively discuss every concept of landscape that has been used in geographic science, but simply to highlight its more important and currently accepted definitions. That said, it is a natural consequence to consider that geodiversity and landscape cannot be treated on the same level or with the same approach – at least considering the concept of geodiversity here presented – because it includes society as an important (sometimes the most important) element of the environment, space or geographic region. On the other hand, it is possible to characterise and evaluate the geodiversity of a selected landscape or selected physico-geographical region (microregion, mesoregion, macroregion).

Besides, the "invisible" elements of the abiotic environment – such as soils, fossils, caves, processes – cannot be approached at a glance, as it is usually considered when analysing landscapes. "Invisible" elements of the abiotic environment (e.g. soil, lithology) are important elements of natural landscapes.

Some authors (e.g. Reynard and Giusti 2018; Sá 2019) talk about the importance of cultural and anthropogenic values in the discussion of geodiversity, including these elements (society, culture) as part of the concept. Here, it is considered that geodiversity should embrace nature only, not society. Including society and culture in the concept of geodiversity only makes it broad and vague, in such a way as to compromise the studies required to fully address the wanted growth in scientific production about the relationship between biotic and abiotic nature (e.g. the biodiversity/geodiversity relation, as pointed out by Boothroyd and McHenry (2019) or Ibáñez and Brevik (2019).

Moreover, it is worth considering that there is a science that already covers processes and relationships between both society and nature, namely geography: the Royal Geographical Society (2020), for example, defines geography as a science that connects social sciences and natural sciences, human geography being concerned with the dynamics of cultures, societies and economies, and physical geography being related to the understanding of the dynamics of (natural) landscapes and the environment. It seems, in these terms, that there is no need to introduce another paradigm in the same sense. Thus, the idea of abiotic nature is reinforced here only in the concept of geodiversity, which would not allow landscape analyses in the same approach, but mainly cultural landscape and readings of nature. The cultural perception of nature, as pointed out by Reynard and Giusti (2018) has already been addressed in science by the so called "Geography of Perception" (e.g. Tuan 1974). It could also be addressed by the so called "Cultural Geography" (e.g. Claval 1995). In all contexts, the cultural analysis of landscape seems to be linked to human geography or social sciences, which in general do not study nature at all (e.g. Santos 2008; Melgaço 2017).

On the other hand, it is possible to talk about a "secondary geodiversity", as pointed out by Kubalíková et al. (2016). This concept means that, besides the existence of "primary geodiversity" (abiotic nature), there would also be a man-made/anthropogenic geodiversity (secondary geodiversity) – for example, anthropogenic geosites such as old quarries, pits or underground landforms. Secondary geodiversity, as much as the primary geodiversity, has large potential in geo-education and geotourism, and could effectively be considered the anthropogenic partner of geodiversity.

Categorising geosites

After Brilha (2016), a geosite is considered as having one or more elements of geodiversity, being well delimited geographically and having scientific characteristics of unique value (sites having other characteristics of high value, such as educational, cultural, aesthetic, touristic, or other, would be considered "sites of geodiversity"). Following the concept of geoheritage presented here, it is necessary to accept the existence of geological sites, geomorphosites (Panizza 2001), pedosites, hydrosites and climosites.

Geological sites in general represent unique scientific areas from palaeontological, palaeo-environmental, sedimentological, marine, igneous and caving perspectives, as well as singular areas related to the geological history of Earth, among others. Geomorphosites, as presented by Panizza (2001), are geoforms with significant and particular geomorphological attributes that qualify them as components of the cultural heritage of a territory in terms of scientific, cultural, socio-economic and scenic values. Geosites, geomorphosites, pedosites, hydrosites and climosites are here considered as sites of unique scientific value, as postulated by Brilha (2016).

The existence of igneous geomorphosites, sedimentary geomorphosites, coastal geomorphosites, hydric geomorphosites and karstic geomorphosites is here considered, among other kinds that could still be taken into account. Pedosites would have as many categories as the main soil types (e.g. sand pedosites, silt pedosites, clay pedosites, podzol pedosites, organic pedosites, luvisol pedosites, regosol pedosites, etc.). Hydrosites would be related, for example, to particular river springs, singular waterfalls or special oxbows, so there could additionally be fluvial hydrosites, geomorphic hydrosites, lagoon hydrosites, besides other classifications that could appear in the future.

Climosites may be much rarer, considering that they are a kind of intangible heritage, but special situations, such as the presence of microclimates related to forested areas in very densely urbanised and developed areas, or the summit of very high alpine peaks, could be considered as such. In this case, there could be urban climosites, rural climosites, alpine climosites, tropical climosites and any other combination of types of climates and geosites that future research could find.

Final considerations

When scientific production related to geodiversity appeared, mostly in the field of geology, it was considered as a new paradigm in the geological science (Gray 2008). Effectively, to geology, which worked mostly with rocks and geological processes, and had just started to look at the ensemble of the abiotic environment, this was and still is a completely new approach.

What has not yet been considered, it seems, is that geodiversity, and that which accompanies it (e.g. geoheritage) is also a new paradigm to geography. The concept of geodiversity, though still in the process of refinement, already has numerous variations, and none of those fit in any of the geographical categories of analysis. It is very close to physical geography, but this branch is deeply committed to abiotic elements as much as to biotic environments, and also society. In such a context, it is clear that there is a new scientific production to evolve and multiply in those perspectives, as has been shown in the preceding paragraphs. This seems to be a necessary step in order to contribute to the development of new approaches in geodiversity and geoheritage domains.

It has been considered (Boothroyd and McHenry 2019) that expanding the definition of geodiversity to include climatic and aquatic parameters may risk diluting the concept to biologists. It would be especially negative for the construction of the necessary complementary approach to biodiversity/geodiversity, in order to understand and protect the Earth's abiotic/biotic features, dynamics and processes, which are thoroughly linked to each other. Effectively, biotic nature depends on abiotic nature to exist, while animals and plants are also important to many geological, pedological and geomorphological processes and features. Thus, considerations of an eventual dilution of the concept of geodiversity through the addition of a new element seem somehow out of the question, considering the importance of water and climate to biodiversity itself.

Increased cross-disciplinary collaboration would probably be the way to get to the necessary biotic/abiotic complementarity in scientific production, as a way to bring ecology and geosciences closer to one another, possibly by increasing quantification and modelling of geodiversity, as well as by standardising methods and goals, as preconised by Ibáñez and Brevik (2019) and Ibáñez et al. (2019). The ways are open, and the inclusion of other experts in the field of geodiversity/abiotic nature seems an important step to get there.

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