Teaching Geoethics

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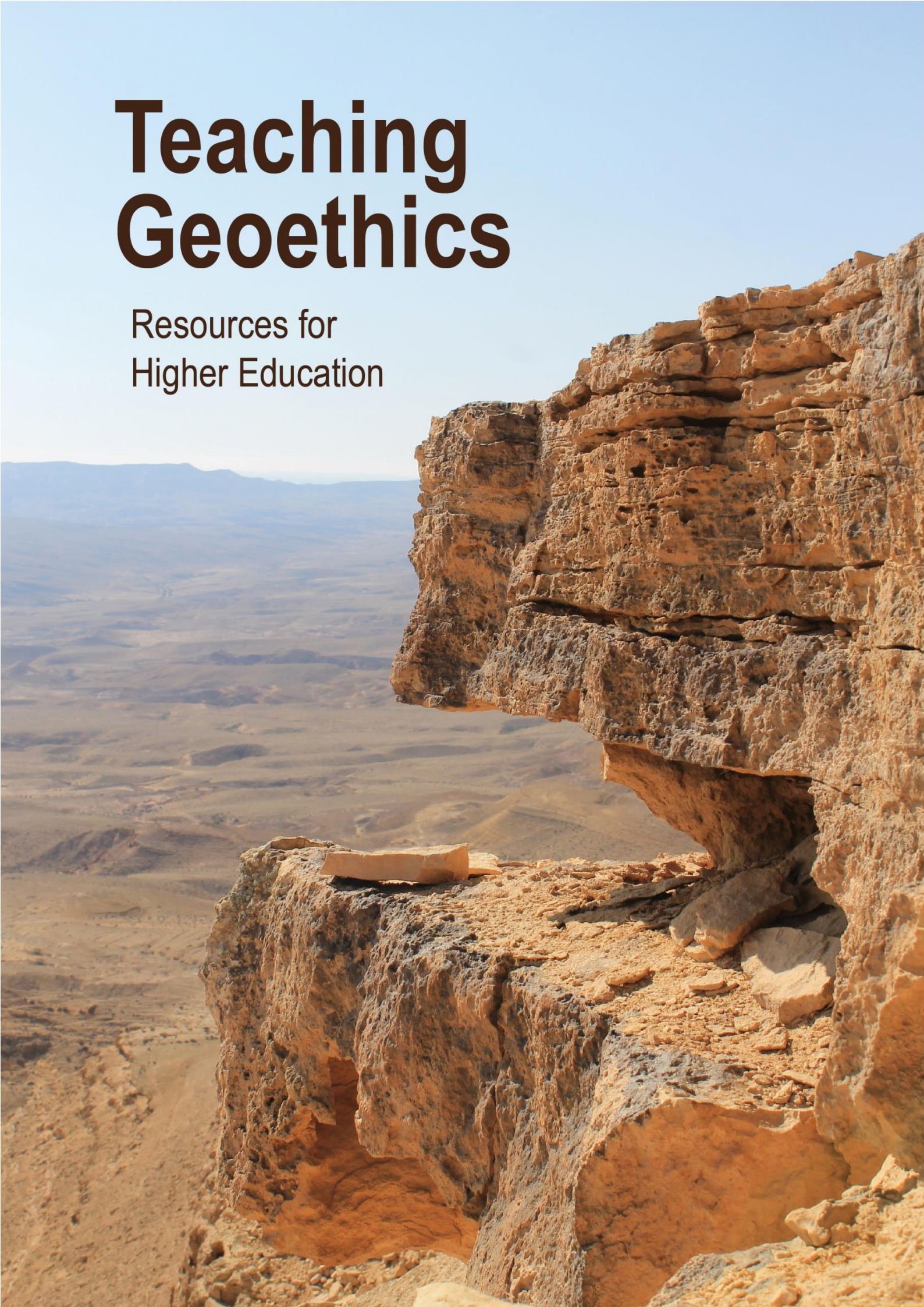

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CONTENT

Chapter 5

Geoethics and geoheritage

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CHAPTER 5. GEOETHICS AND GEOHERITAGE

SUMMARY

There has been little discussion about the relationship between geoethics and geological heritage, probably because both topics are relatively new in geosciences and still little understood. Here we provide a short overview of the relevant concepts of geodiversity, geological heritage and geoconservation. Palaeontological heritage is specially highlighted, as fossils are probably among the most threatened elements and need additional, more effective protection measures. Furthermore, we present some ideas to promote awareness and reflection in students and pre-professional training of geoscientists around some themes that directly link geoconservation principles with geoethical issues.

1 GEODIVERSITY, GEOHERITAGE AND GEOCONSERVATION

1.1 Background and main concepts

Geodiversity can be defined as "*the natural range (diversity) of geological (rocks, minerals, fossils), geomorphological (landforms, topography, physical processes), soil and hydrological features. It includes their assemblages, structures, systems and contributions to landscapes*" (Gray, 2013, p.12). This term was introduced in the first years of the 1990 decade but, after 30 years, it is still generally unknown by the majority of the society. Brilha et al. (2018) make a review of this concept and show how geodiversity is connected with other natural systems and, in particular, how it is determinant to guarantee human sustainability based on the use of extractable and non-extractable natural resources (Figure 1).

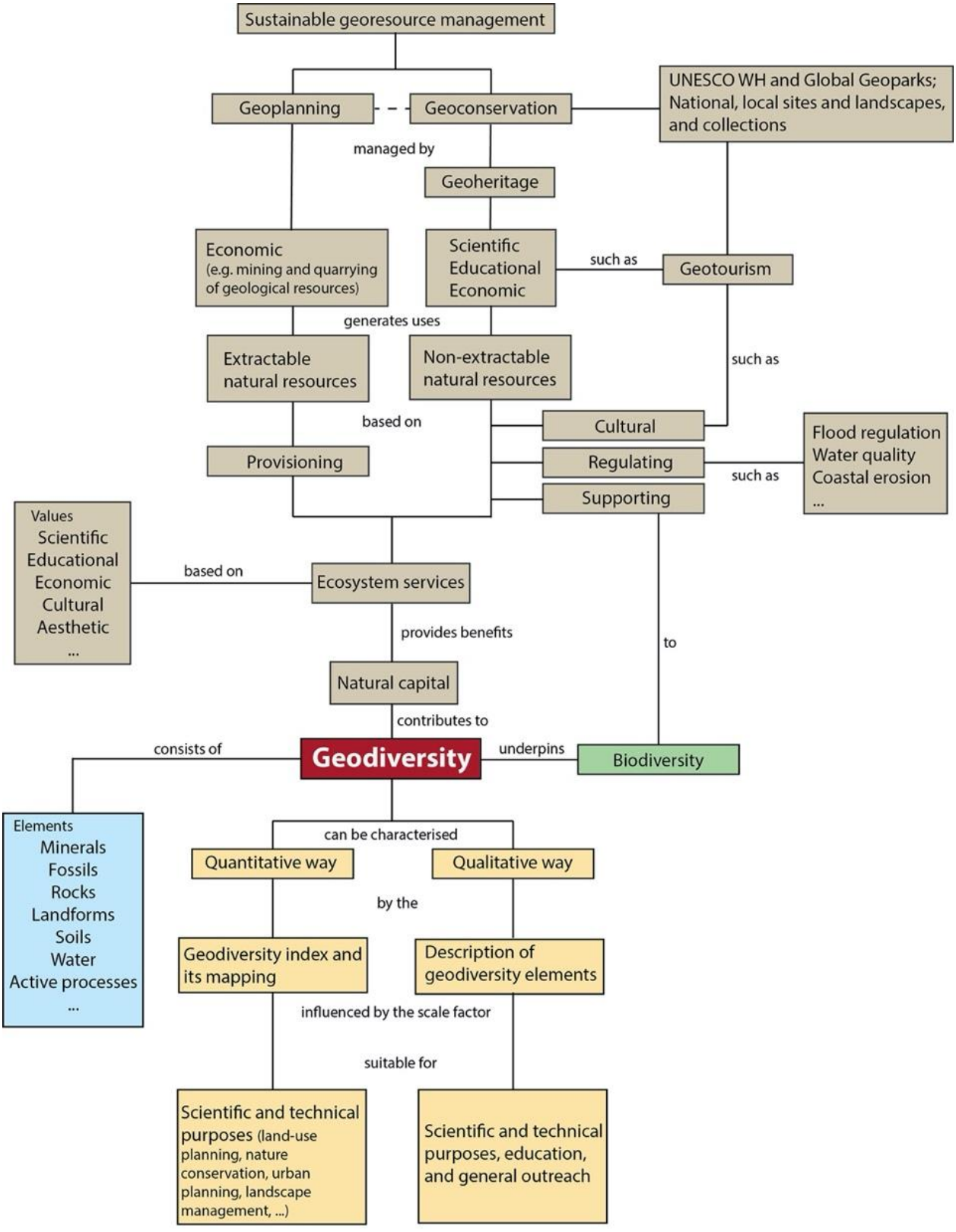

Figure 1. Network of definitions and relationships starting from the concept of geodiversity (Brilha et al., 2018, p. 20)

The smart use of geodiversity elements by the society demands a solid knowledge of how Earth systems work. To obtain scientific data that allow geoscientists to know better our planet, it is essential to guarantee access to geological materials (minerals, rocks, fossils, soils, landforms) with some special characteristics. In many domains of geosciences, some of these data are obtained directly in the field. In other domains, samples are collected for further analysis in the laboratory. However, in both cases, geological sites that are object of study must be preserved as evidence of the history of the planet, thus allowing the advance of geosciences (Figure 2). These places are known as geosites and the set of geosites in a given territory constitutes its geological heritage (*in situ*) (Brilha, 2018, in press).

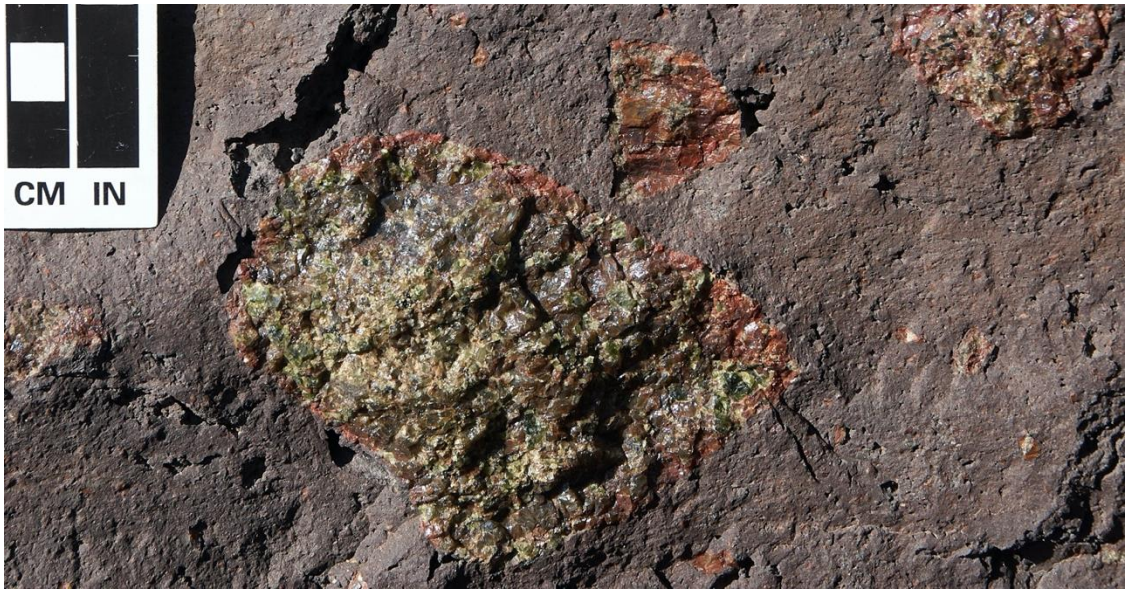

Figure 2. Olivine-rich xenoliths in basaltic rocks. Samples from this outcrop have high scientific value because they provide important geochemical data to understand volcanic processes (Lanzarote Island, Canary Archipelago, Spain). Photo by J. Brilha

Geological samples organized in scientific collections available for scientific research are also part of the geological heritage (*ex situ*) (Figure 3).

Figure 3. Ammonite specimen in a scientific collection, an example of *ex situ* geoheritage (Natural Sciences Museum, University of Zaragoza, Spain). Photo by J. Brilha

All these special *in situ* and *ex situ* geological features should be kept in the best possible conservation status and must have some characteristics that differentiate them from other similar geological features. The scientific relevance of a geosite is also attested by national and international publications directly related to its geological value.

In addition to scientific use, geological sites may have other types of sustainable use. It is the case of an educational use, when geodiversity elements can be easily understood by students of different school levels, in addition to have a good accessibility and safety conditions for students and teachers (Figure 4).

Figure 4. Basalts with columnar jointing as an example of geological site with high educative value (Iceland). Photo by J. Brilha

In other sites, geodiversity elements are natural attractions that can be used for the promotion of leisure and tourist activities. For a recreational and tourist use, the aesthetic and cultural values of these elements are particularly relevant (Figure 5).

Figure 5. The aesthetic value and uniqueness character of Iguaçu waterfalls justify the high touristic visitation of this geosite (Brazil/Argentina). Photo by J. Brilha

The vast majority of geodiversity elements with no scientific value but with other type of values are designated as geodiversity sites but this does not imply that they should not be protected and valued following geoconservation strategies (Brilha, 2018).

1.2 Why do we need geoconservation?

Geoconservation aims at the protection and management of geosites and geodiversity sites, including the management of geological collections. There are specific methods to promote geoconservation, namely the inventorying and quantitative assessment, statutory protection, conservation, promotion and interpretation, and monitoring of sites (Brilha, 2018).
Geoconservation measures are needed because many geological sites worldwide are under threat due to several anthropic factors:

i) *Cultural and science illiteracy* – Decision-makers and the society in general have a very low awareness about geology and the importance of geodiversity elements for the natural capital, ecosystems services, and human well-being. Therefore, public decisions towards geoconservation tend to be delayed or completely overlooked.
ii) *Unsustainable mining* – In spite mining of mineral and energy resources is absolutely vital for the human development, unsustainable mining may put many relevant geological sites at risk.
iii) *Urban development* – The rapid expansion of cities towards rural areas due to the human population growth and migration from the countryside to urban areas is responsible for the destruction of many geological sites.
iv) *Deficient statutory protection* – Without a solid statutory protection at the international, national or local levels, the preservation of geological sites is fragile and frequently inconsequent.
v) *Inefficient administration* – A public administration without trained staff, a solid geoconservation strategy and proper funding, the vulnerability of geoheritage increases in many countries.
vi) *Smuggling and illegal collecting* – Fossils, minerals, and rocks are being stolen from many countries feeding international smuggling networks that provide huge benefits to speculators.
vii) *(Some) scientific research* – There are geosites strongly affected by deficient scientific sampling procedures that do not take into account the different types of values of some outcrops.
viii) *Unsustainable tourism and leisure activities* – Mass tourism in areas with fragile geological features (for instance, caves, soft and unconsolidated substrates, rare fossils) can negatively affect many geological sites.

Geoconservation should be also considered an applied geosciences (Henriques et al., 2011). In fact, mainly during the last two decades there is a growing volume of scientific knowledge developed using specific methods. In addition, there are research schools and teaching that produces master and PhD theses, discussion among experts in scientific events of all types, and publication of peer-reviewed papers in dedicated indexed scientific journals. All these characteristics are typical of any other geosciences.

2 PALAEONTOLOGICAL HERITAGE

Among the different elements of geodiversity, fossils are particularly affected by many of the threats mentioned above. Accordingly, the palaeontological heritage is here highlighted as it demands strategic and more effective protection measures.

2.1 Generalities about fossils and palaeontological heritage

Fossils are any evidence (remains, impressions, moulds, casts, traces, biochemical molecules, etc) of once-living organisms from a past geological age that are preserved in the materials of the Earth's lithosfere (i.e., they are mostly found in rocks with a sedimentary nature). They represent

a relevant component of geodiversity with the unusual capacity to connect people with our natural environments and also, importantly, with our origins and past. Fossils inform about the environment where past organisms have lived and, together with their surrounding environment of deposition (usually, the environment of accumulation of the sediments corresponding to the rock in which fossils are found), give palaeontologists a fuller understanding of the history and evolution of the life on our planet.

Given the exceptional nature of the process of fossilisation, a fossil is, by definition, a unique or rare and non-renewable natural object and, as such, a highly valuable asset (Henriques & Pena dos Reis, 2015). However, in all fossils we can find the convergence of three different histories: *i*) Since a fossil is the evidence of a once-living organism, it is the result of an evolutionary history and, as such, it informs about the past life on Earth and the relationships with current biodiversity. *ii*) Since the humankind forms part of this evolutionary history, fossils inform as well about our own history as living beings (hence, the evolutionary anthropology or the study of humankind from a palaeontological perspective receives a lot of attention), but also about our changing role in nature and our relationships with Earth. *iii*) Since a fossil is the result of a fossilization process (a complex natural biological and geological process), it has also its own geological history that could be different of the rock containing it and that still continues while it is not removed from the site. Palaeontology, or the study of fossils, is then placed at the intersection among geological, biological and archaeological/anthropological disciplines. The palaeontological heritage shares, therefore, common characteristics with both our natural and social/cultural/historical heritage (despite ongoing debate among some geo-researchers), and cannot be interpreted or studied without this synergetic perspective. In common with the natural heritage, fossils are formed in and by nature; while the obvious link with the social/cultural/historical component is the popular fascination of fossils that lead to collection of these elements for hobby (Alcalá & Morales, 1994).

It is also important to underline that fossils are an evidence of the evolutionary theory, which can raise conflicts with religious beliefs (science vs. religion) because they are real evidences of past life and extinctions. Due to these singular features, it has been argued that palaeontological heritage can be a separate entity from geoheritage, despite fossils are geodiversity elements (Meléndez & Soria-Llop, 2000).
The scientific value of fossils is due both to the fossil itself and the rocks containing it. Then, the term palaeontological heritage refers to both a "set of rocks containing fossils, the palaeontological sites, and all the fossils extracted from them". In this sense, it is comparable to other geoheritage such as the mineralogical and the archaeological heritage.

2.2 Management of palaeontological heritage

Fossils are valuable objects that offer some type of benefit and are of interest to society. There is a plethora of reasons that attract people to fossils (which is particularly evident for dinosaurs and anthropoid primates) which, on one hand, can contribute to promote learning for students and public in general (since they explain something amazing) but, by the other hand, may result in a direct, serious impact and a hazard for the integrity of the fossil record. There is a long and complex process from the discovery of a fossil in the field (which requires actively searching likely deposits and careful excavation of the fossil) to its incorporation into a collection and use in exhibition and dissemination, that can be synthesised as follows:

1) finding --- 2) extraction --- 3) preparation/conservation --- 4) collection management --- 5) study/publication --- 6) exhibition --- 7) dissemination.

Usually, only macrofossils (i.e., fossils that are visible at the naked eye) are used for exhibition, while both macro- and microfossils (i.e., fossils that can only be seen with a magnifying glass or a microscope) are equally relevant to the scientific knowledge and research (Figure 6).

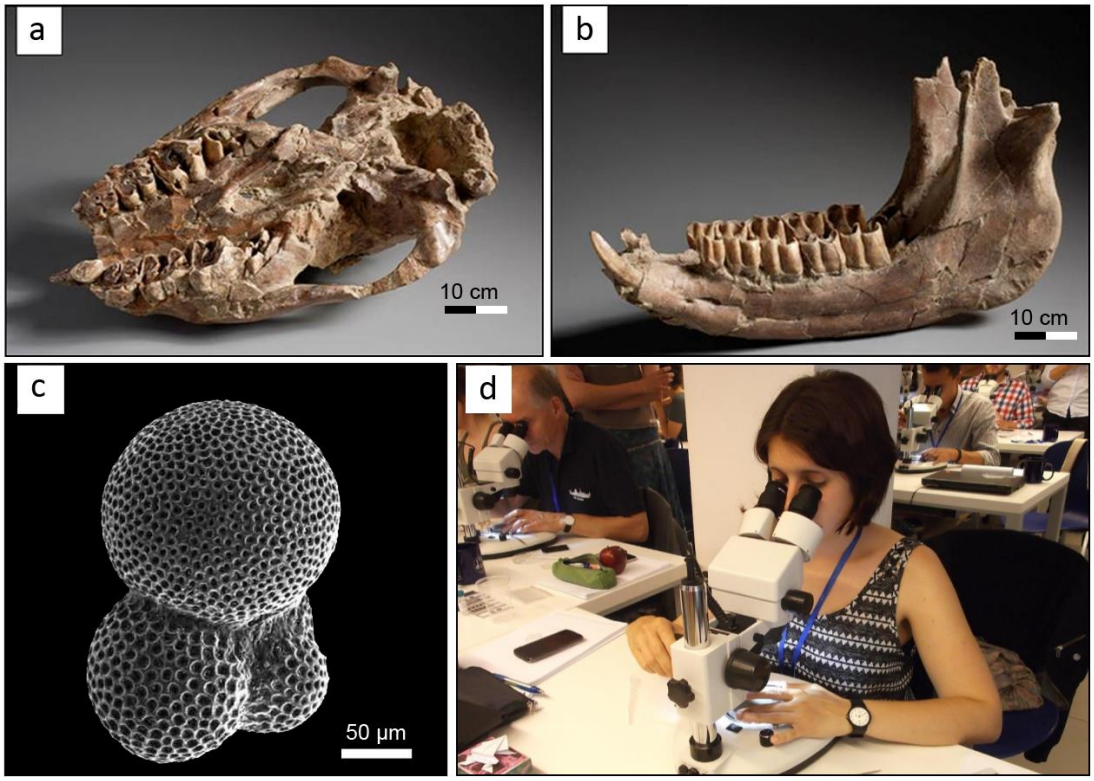

Figure 6. a) Skull (MPZ-2006/285) in ventral view and b) complete jaw (MPZ-2006/6) of a middle Miocene (~12 million years) rhinoceros *Alicornops simorrense* as an example of macrofossil. Images provided by the Natural Sciences Museum, University of Zaragoza, Spain. c) Specimen of a planktonic Foraminifera *Eoglobigerina* (Arenillas & Arz, 2013, p. 164) and d) micropalaeontologists at work

A palaeontological site is a particular location (or group of nearby occurrences) in which fossils (of any type and concentration) are present (Alcalá & Morales, 1994). It is evident that not all fossil occurrences are palaeontological heritage, such as not all paintings are art nor all the territory of a country can be declared as geoheritage. This is clear in the case of microfossils, as they are components of many sedimentary rocks (Figure 7). Microfossils have been neglected in geoconservation, but type-localities and stratotypes that are formally defined on the basis of microfossils are relevant components that need to be considered as palaeontological heritage as well.

Figure 7. Microfossils (alveolines) in limestones. Photo by J.A. Arz

In a first step, palaeontologists have to decide which fossils and sites have the sufficient importance to be considered as palaeontological heritage and, once decided, how to manage them in the proper way. There are three different groups of criteria that may help to resolve this task (Alcalá & Morales, 1994):

i) *Scientific criteria* – Nature of fossils (fossils of exceptional importance); geological age of the rocks; type localities (i.e., those from which certain species have been first recognised and formally defined); degree of preservation; association with archaeological remains; diversity of fossils (for example association of plant and animal remains); taphonomic (i.e., the process leading up to preservation or fossilisation) information; bio/chronostratigraphical relevance (sites which date important geological formations at international level); wider geological interest; and level of knowledge (sites that have provided new knowledge about a particular topic).
ii) *Socio-cultural criteria* – Fragility; geographic location; vulnerability to damage; historic value; educational interest (a criterion of special relevance to this chapter as it informs about the potential of a site for use in education); touristic interest (similar to the previous); and complementary value (sites in places already protected for other reasons).
iii) *Socioeconomic criteria* – Urban value (sites in urban areas potentially available for development); mineral value (sites associated with mineral exploitation); public works (sites linked with works); and economic value.

Note that many of these criteria might create various ethical conflicts and consequently are directly related to geoethics. For example, public works (especially for transport, water and power), mining activities, engineering projects, etc. can destroy sites of relevant importance to palaeontology, but they can also allow the discovery of new fossil occurrences. Also, conservation is needed to protect fossils and sites from loss and destruction through illegal sampling and also to regulate the selling and exportation of fossils.

In terms of regulations, and because palaeontological heritage is considered a type of heritage in many countries, there are legal measures for a correct protection and management of fossils and palaeontological sites. These laws vary widely from country to country, with some governments being less strict than others (Wimbledon & Smith-Meyer, 2012). A relevant difference among

countries concerning fossil collecting is the private or public ownership of the surface and underground.

3 GEOETHICAL ISSUES RELATED WITH GEOHERITAGE

It is evident from all the above that geoheritage offers great opportunities to provide education of geosciences for the benefit of citizens and also to promote a reflection on a plethora of aspects. Thus, geoparks, geosites and museums, among other resources, can be successfully used as tools to support geoethics learning and facilitate student training. However, the inventory, conservation, and management of geoheritage raises some geoethical issues that are still poorly addressed in the literature. Some of these issues are briefly presented in the following paragraphs, with the purpose to trigger reflective learning and not to give a final answer to some of the dilemmas.

3.1 Illegal collecting of geological specimens (fossils, minerals, meteorites)

In recent years, the popularity of fossils (and minerals to a lesser extent) as collectible and commercial items has significantly increased. Most probably, this is in part attributable to the growing prominence of dinosaurs in movies and TV shows, as they are attractive and fascinating elements for the public. As a result, commercial collections have dramatically increased, creating competition for scientific collectors, although the commercial appropriation of fossils and minerals is illegal in many countries.
Commercial collecting raises therefore many ethical issues and has a detrimental effect on both education and science, as fossils, minerals and meteorites are irreplaceable educational and scientific objects. Picking up small fossils or minerals, or invertebrate fossils, seems harmless enough, but, should amateur collectors be allowed to collect them? And what about professional geoscientists?

For instance, the increase in the economic value of fossils has limited the possibility of public museums and educational centres with tight budgets acquire fossils for their collections. Concerning science, the irresponsible sampling of geological specimens by amateurs and collectors has led to a scientific loss of valuable specimens. The sampling of fossils without following a correct (scientific) protocol contributes to a permanent loss of information of the surrounding environment of deposition and the geological context, many times of much more interest for palaeontologists than the fossil by itself.

It is therefore crucial to promote sound criteria to assist geoconservation actions and determine what regulations are needed for the inventory, evaluation, conservation, valuation and monitoring of the palaeontological heritage. Public administrations in charge with the management of geoheritage should be assisted by geoscientists, particularly when they have a lack of staff with proper training (Alcalá & Morales, 1994). Some regional administrations in Spain are a good example of management as they have already included a professional palaeontologist in their regular staff.

3.2 Smuggling of geological specimens versus economic revenue of deprived communities

Another perspective concerning illegal collecting of geological specimens is related with economic and social issues in local communities. In some countries, the collecting of minerals, fossils and meteorites is a source of income for many poor families in rural areas. Without alternatives, this activity is the only resource available for non-educated people and with guarantee of a regular income flow.

In many places, like in the Tafilalet region (Morocco, North Africa), the search and massive digs of fossils for commercial purposes is leading to the destruction of sites and specimens (Gutiérrez-Marco & García-Bellido, 2018). However, this is not all bleak and the same trade of fossils can

bring a benefit for science, as there are thousands of new findings (especially marine invertebrates such as trilobites and cephalopods) thanks to massive exploitation of fossiliferous layers, which allow a better understanding of taxonomic, taphonomical and palaeoecological aspects of past organisms.

3.3 Selling of fossil replicas: fakery or handcraft

Many fossil groups are very limited in the number of specimens and therefore it is not possible to have them in museum collections all over the world. For such groups, the production of replicas is an excellent solution. In several natural history museums, the fossil exhibition is almost entirely based on replicas, particularly in what concerns complete skeletons of dinosaurs or other complex, heavy animals.

The production of replicas can be seen under three different perspectives:

i) As an *educational and scientific resource* – When the availability of real fossils is limited and expensive.

ii) As a *handcraft* – When artistic fossil recreations are produced and sell as any other economic activity (Figure 8).

Figure 8. Traditional selling of minerals and fossils in Morocco. The “giant ammonite” on the right can be considered an example of local handcraft. Photo by J. Brilha

iii) To *simulate true fossils* with a clear purpose to deceive (particularly non-expert) buyers.

Countries where fossil fakery is common include USA, Colombia, Peru, Russia, Germany, France, and (especially) Morocco (with marine trilobites) and China (with *Archaeoraptor* being one of the most conspicuous recent fossil fakes).This practice has a negative impact on both science and society, as many of the fake material can be difficult to identify as such (sometimes even to experts) and is sold at higher prices to museums and educational institutions where it is exhibited as a real fossil (Budik & Turek, 2003).
The production of fossil replicas with a licit aim may decrease the pressure on limited outcrops and can constitute an economic alternative for local populations.

3.4 Mining and development works: a threat or an opportunity

Mining and urban development can lead to the destruction of many geological features with scientific, educative, and touristic values. Sometimes, mining companies are interested in exploring a certain area where geoheritage has been already identified, causing significant impacts on this natural heritage.
However, mining activities and public works give access to rocky massifs where new geological occurrences with geoheritage relevance may be identified. Mining of fossiliferous formations is, quite frequently, a source of new fossils that can lead to the identification of new species. The same happens with mineralogical heritage. Many mineral samples with scientific value are only available because mining exploitation brought those samples to the surface. The truth is that without mining, many important mineral and fossil specimens would remain completely unknown for science.

The palaeontological site of Lo Hueco (in Central-East Spain) is a good example of potential conflict between infrastructure development and preservation of palaeontological heritage (see Educational Resource). This site yielded in 2007 an enormous and unusual concentration of Late Cretaceous dinosaurs (70-80 million years) (Ortega et al., 2008; Barroso-Barcenilla et al., 2009) thanks to the works carried out for the construction of new high-speed railway. There were no signs of any fossils in the surroundings, but a new palaeontological heritage came to light. Fortunately, the railway works stopped for a while to facilitate the identification, documentation and protection of fossils. After this research, it was possible to introduce a modification in the construction works of the railway in order to protect the site. This was an exceptional example of cooperation between the company ADIF (Administrador de Infraestructuras Ferroviarias) and the palaeontologists, with mutual benefit for the government, the society and the conservation of this heritage.

3.5 Mineral and fossil shows: an educational occasion or an incentive for smuggling of geological specimens

Mineral and fossil fairs/shows/festivals are organised all over the world. Some of them have already a worldwide recognition, such as the Tucson Gem and Mineral Show which gather each year around 4000 trade companies in Arizona, USA. Smaller events are frequently organized by universities and museums, with the participation of professional sellers that display fantastic specimens and, of course, with the purpose to do business (Figure 9).

Figure 9. Example of vitrines showing several samples of minerals in a fair (left; Photo by J. Brilha) and a replica of *Tarbosaurus* skull from Mongolia in a shop (right; Photo by B. Azanza) to sell

While these events may have an educational character, raising awareness of the public for a usually less known natural world and eventully stimulating young people to follow a geoscientific career in the future, one should question about the provenience of all the samples displayed in these events.

Were they collected following the national legislation in each country? The local collectors in remote areas and many times in poor countries were they properly paid for their work? Are there fossil and mineral sites with high scientific relevance being lost due to overcollecting to feed the international market? Are countries aware that their natural heritage is going out of the country? Do these countries collect taxes as they do for any other commercial activity?

These are just some of the issues related with fossil and minerals shows that should be discussed under a geoethical perspective.

3.6 Location of vulnerable geosites: reveal or keep secret?

There is increasintg interest on geotourism, both by promoters and visitors (Dowling, 2011). In spite it is not restricted to geoparks, the strategy of the 147 UNESCO Global Geoparks is strongly supported on geotourism. Geotourism promotes the visit to geological features, not only focused on geological interpretation but also on the links that can be established between these features and biological and cultural character of communities. Geological sites with high aesthetic value, good accessibility and safe visiting conditions can be converted into touristic attractions with high potential to generate an economic activity.
What about if a geological site with high geotourism potential is vulnerable due to an intrinsic fragility of the geological element or due to possible physical degradation caused, intentionally or not, by visitors?

Should a manager open a certain geological site to visitors when it is not possible to guarantee its conservation? Fossil sites are a good example of this dilemma. Many fossils sites have the potential to attract visitors but, without proper conservation measures, these visitors may collect and vandalise fossils, contributing to the loss of the site value and consequently to a decrease of the number of visitors.

In geological sites, there is always a risk that tourists collect and take fossils, rocks, minerals, etc. What about if this activity is allowed in informal sites or fossil parks where visitors appreciate the opportunity to "act like a palaeontologist" (Figure 10)? Despite fossil parks may have an educational character, one should question about the ambiguous message that is being presented concerning geoconservation.

Figure 10. Invertebrate fossils on the surface can be easily collected by visitors. Because fossilisation is a continuous process, once fossils are freed from the rock they are more susceptible to be incorporated in future rock bodies by current geologic processes (for instance, they could be dragged, damaged and deposited in other place by a flooding) if they are not collected. Photo by N. Kelpšaitė

3.7 Artificialization of show caves: a way to promote visitation or a loss of value

Karst caves are one of the most popular nature attractions in the world. The underground environment raises a great curiosity among children and adults due to uncommon landforms such as stalactites and stalagmites. During the 20th century, many caves were heavily developed to receive a growing number of visitors. Quite frequently, these development works have introduced a great disturbance in the natural environment, with significant changes in the accessibility and visiting conditions, such as paved trails, artificial lightning (sometimes very colourful), music and even some artificial structures such as benches and stairs, not rarely implying destruction of some natural features (Figure 11).

Figure 11. Cacahuamilpa Cave, the most visited cave in Mexico, discovered in 1883 and with about 350.000 visitors per year (Palacio-Prieto & Gómez-Aguado de Alba, 2014). Photos by J. Brilha

Nowadays, this type of development in caves is not acceptable, mainly because it introduces dramatic changes in local biodiversity.

The challenge for managers of modern show caves is the following: should the cave be prepared to receive different types of public, children, adults and senior citizens, people with disabilities, allowing all the society to have an underground experience? Or should the cave be kept in the most natural state possible but limiting its accessibility to just a fraction of possible visitors. While the former implies an artificialization of the cave, the latter gives a more realistic feeling to visitors and cause much less impacts in geodiversity and biodiversity.

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