International Journal of Geoheritage and Parks 7 (2019) 226–236

Contents lists available at ScienceDirect

International Journal of Geoheritage and Parks

journal homepage: http://www.keaipublishing.com/en/journals/international-journal-of-geoheritage-and-parks/

Geodiversity, geoheritage and geoconservation for society

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ARTICLE INFO

Article history:
Received 23 September 2019
Accepted 26 November 2019
Available online 28 November 2019

Geology is part of the planet's "natural capital", the stock of global natural assets. These assets provide many benefits for society, often referred to as "ecosystem services". However, traditionally these have mainly focused on biotic services and have undervalued the abiotic ones. The latter are known here as "geosystem services" and they all derive from the geodiversity of the planet. This paper outlines how society benefits from three aspect of geodiversity – topographies, geological materials and physical processes. It also particularly argues that society benefits from geoconservation of the planet's geoheritage, citing the criteria for designating UNESCO World Heritage Sites, UNESCO Global Geoparks and national protected areas, the public interest in visiting spectacular geological places and the economic benefits this geotourism brings.

1. Introduction

Planet Earth is often described as the "third rock from the Sun", emphasizing the fact that it is essentially a physical entity but with an outer living skin and a 70% oceanic cover. Because of its complex, 4.6 billion-year history involving moving plates, changing climates and a host of catastrophic events, it has developed an extremely complex geology and geomorphology. Although this presents considerable problems for society, including a range of natural hazards and uncertain ground conditions for engineering projects, it has also provided us with a huge diversity – a geodiversity – of topographies, geological materials and physical processes that societies over the millennia have exploited for their own uses. Geodiversity has been 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 paper aims to outline the many benefits that geodiversity brings to our modern society. One of these benefits is the geological and geomorphological evidence for understanding the history of the Earth and the evolution of life and the paper therefore makes the case for conserving this geoheritage. In order to understand how geodiversity and geoheritage benefit society, we first need some background on the concepts of 'natural capital' and 'ecosystem services'.

2. Natural capital

"Capital" is most commonly used in the economic and business worlds to describe the stock of financial assets. Over the last 30 years or so, other uses of the word "capital" have been introduced including manufactured capital (e.g. roads, buildings, machines, produce) human/social/intellectual capital (e.g. health, knowledge, culture, institutions) and natural capital (the stock of natural assets). The most important definition of natural capital is given by the *World Forum on Natural Capital,* which defines it as "the world's stocks of natural assets which include geology, soil, air, water and all living things" (www.

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https://doi.org/10.1016/j.ijgeop.2019.11.001

naturalcapitalforum.com). A very similar definition has been developed by the *Natural Capital Coalition,* another international organisation: "Natural capital is another term for the stock of renewable and non-renewable resources (e.g. plants, animals, air, water, soils, minerals) that combine to yield a flow of benefits to people" (https://naturalcapitalcoalition.org/natural-capital-2/). These definitions have the advantage of being clear, concise and comprehensive, and they include geology/minerals, recognizing their place as the foundation of the planet. These or similar definitions have been adopted by many international or national organisations and are being used in many existing environmental management and analytical approaches such as natural capital accounting. Thus, the geodiversity of the planet's geology (including its geomorphology) are generally regarded as part of natural capital.

Natural systems are complex and often subject to irreversible environmental change. Human concern for environmental impacts has a long history (Mooney & Ehrlich, 1997), but has been accelerating in the last 50 years. As of May 2019, there is even now international agreement from a working group of the Subcommission on Quaternary Stratigraphy (http://quaternary.stratigraphy.org/working-groups/anthropocene/) that we are now living in a new geological period - the *Anthropocene.* Humans have become a significant threat to natural capital, which has been in decline for centuries and is continuing (e.g. Costanza & Daly, 1992; Dearing et al., 2012). This is a major driver for the natural capital approach which seeks to slow, stop or, if possible, reverse this decline and to produce a sustainable management of the planet's stock of resources, both biotic and abiotic, for future generations. The mismanagement of natural capital often occurs because its full value is not recognized in decision-making.

3. Ecosystem services

'Ecosystem services' is a related approach in that natural capital is a stock, and from it flow significant benefits for society, usually termed 'ecosystem services'. The human impacts on the natural environment, referred to above, led a group of ecologists in America in the 1990s to "lament the near total lack of public appreciation of societal dependence upon natural ecosystems" and to resolve to produce "a rigorous, detailed synthesis of our current understanding of a suite of ecosystem services and a preliminary assessment of their economic value" (Daily, 1997b, p.xv). The first result was the book *Nature's Services: societal dependence on natural ecosystems* edited by Gretchen Daily (1997a). She defines 'ecosystem services' as "the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life" (Daily, 1997c, p.3). Daily's book and this definition typify most of the writings on ecosystem services in that they are overwhelmingly concerned with biology, despite Tansley's (1935) long-standing definition of an 'ecosystem' as including the interacting "non-living" parts of the environment.

In 2000, concerned about the consequences of ecosystem degradation for human well-being, UN Secretary General Kofi Annan, called for a comprehensive study to be published by the world's scientists and social scientists. Their findings were published in the *Millennium Ecosystem Assessment* (MEA, 2005) which provides a state-of-the-art scientific appraisal of the condition of the world's ecosystems, the services they provide for society, and the options for the conservation, restoration and sustainable use of ecosystems. The report classified ecosystem services into regulating, supporting, provisioning and cultural services, but again it is overwhelmingly biocentric. For example, the provisioning services are listed as food (plants, animals), fibre (wood, wool, cotton, etc.), fuel (wood, etc.), genetic resources, biochemicals & pharmaceuticals, ornamental resources (shells, flowers) and freshwater, with no mention of the geological resources of the planet. This situation is confusing in that whereas the *World Forum on Natural Capital* is leading the way in promoting 'natural capital' as including geology, the 'ecosystem services' approach is often excluding it. In some cases, this is a conscious exclusion while in others it is apparently unconscious (Gray, 2018b).

Two other methods of classification of ecosystem services have been proposed. The first, by Haines-Young and Potschin (2013), is the *Common International Classification of Ecosystem Services* (CICES). In it, they discuss the dilemma of whether to include or exclude abiotic services from the classification. At first the decision was to exclude them but "the goal should be a combined classification that integrates outputs across ecosystems and from other natural resources" (Haines-Young & Potschin, 2013, p.11). Following criticism (e.g. by Van der Meulen, Braat, & Brils, 2016), the latest version (CICES, v5.1) presents an "abiotic extension" listing 35 abiotic services, though it is described as an "extension" rather than an integrated and equal partner and is not comprehensive. The second alternative method to the MEA is *The Economics of Ecosystems and Biodiversity* (TEEB, 2010) which aims to assess the global problem of biodiversity loss and ecosystem degradation in quantitative economic and human welfare terms, and proposes solutions targeted at policy-makers, administrators, businesses and citizens. It does not generally include abiotic nature.

4. Geodiversity for society: geosystem services

Given the general exclusion of abiotic nature from the ecosystem services approach, I have attempted to examine the goods and services specifically related to geodiversity and have used the MEA classification method modified to include 'knowledge services', otherwise part of cultural services. This is because of the importance of geology if providing evidence for the evolution of the planet and its living systems. A summary diagram showing the 25 major, 'geosystem services' is shown in Fig. 1. It should be noted, in particular, that all these services derive from the fact that the planet is geodiverse. It is not the intention here to describe all these services in detail: they are fully described in Gray (2013). Instead, a few examples will be given using the three abiotic phenomena that comprise the surface and sub-surface of our planet and mentioned in the introduction to this paper – topographies, geological materials and physical processes.

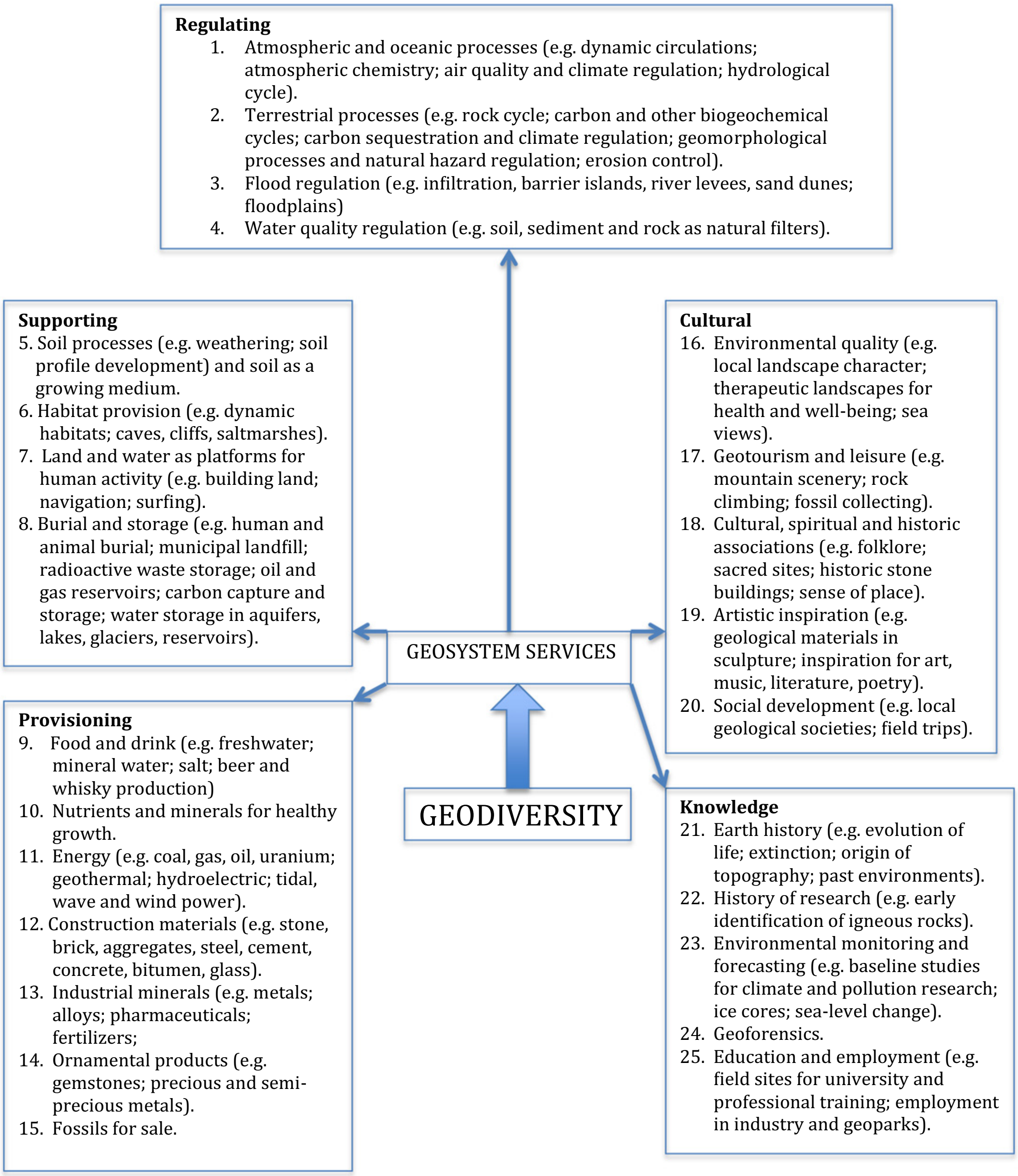

Fig. 1. The 25 major geosystem services, all of which are related to the planet's geodiversity. (From Gray (2018b) with permission of Elsevier).

4.1. Topographies

How does society benefit from living on an uneven land surface?

- It provides us with a sense of place. We recognise where we are, not just from the local buildings, trees, etc. that we see around us, but also from our topographic surroundings, the hollows, knolls, valleys, hills etc. that we see each day as we travel around.
- These topographic surroundings often form the foundations of landscapes that may be highly valued locally or others that may be nationally or internationally spectacular enough to attract geotourists. Examples include caves, canyons, coastal and mountain views (Fig. 2). There is also growing evidence that having access to natural landscapes benefits both physical and mental health (e.g. https://www.mind.org.uk/media/23671047/nature-and-mental-health-2018.pdf).
- Landforms can give us information about how the land surface was formed and lead to a deep understanding of the evolution of the Earth's surface (geomorphology). And since there is often a relationship between landforms and the underlying geological

Fig. 2. A coastal landscape dominated by geology/geomorphology: western Algarve, Portugal.

materials, this gives us a way of prospecting for some geological materials. For example, glaciofluvial landforms such as eskers, kames, kame terraces, etc. are predominantly composed of sands and gravels.

- The land surface provides a platform for a range of human activities, and different land uses take place on different slope angles. Table 1 shows maximum slope angles for a range of human activities/land uses. Some land uses, such as airport runways, require very low slope angles whereas others, such as housing developments, can take place on slightly steeper land. Of course, we have the technology to alter topography but only to a certain extent, and where this does take place it can do damage to important landforms as has happened at certain ski resorts (Bayfield, 2001). Some activities, such as skiing, require steeper slopes and Table 2 gives the American classification of ski runs based on slope angle. Most ski resorts will try to provide a range of ski slopes to cater for the range of abilities in family or other groups. Finally, rock climbers require near vertical cliffs and even overhangs and value the range of geological structures and lithologies from horizontally bedded sandstones to columnar jointed igneous rocks (see also Garcia-Rodriguez & Fernández-Escalante, 2017; Mellor, 2001).
- The land surface also provides a platform for plants and animals to flourish, and different topographies can support different wildlife (Hjort, Gordon, Gray, & Hunter, 2015). For example, several bird, bee and other species nest or burrow into soft sediment cliffs. Arctic and alpine plant species grow on cold mountain tops. Birds are often attracted to lakes, ponds or marshes, including saltmarshes, or nest on rocky islands or hard rock cliffs. The fact that different topographies encourage different species has led to the concept of *Conserving Nature's Stage* (CNS) in which the stage is a metaphor for topography with the actors being the flora and fauna (Anderson & Feree, 2010; Hjort et al., 2015). In turn, this has led to the idea that in times of climate change, conserving topographies is an important means of protecting habitats to which plants and animals can migrate (e.g. Anderson & Feree, 2010; Knudsen, Kay, & Fisher, 2018).
- Some landforms protect society from natural hazards, particularly flooding. Natural river bank levées, coastal sand dunes and saltmarshes are all examples of landforms able to act as flood defence features.

Table 1
Maximum slope angles for a range of activities/land uses.(Modified from Cooke & Doornkamp (1990)).

0.5	International airport runways
1	Mainline railways
	Local aerodrome runways
	Free ploughing
2	Major highways
	Agricultural machinery (weeding & seeding)
	Constructional problems begin
	Soil erosion may be initiated
3	Housing
	Roads
5	Railways
	Heavy agricultural machinery
	Large-scale industrial site development
10	Site development
	Standard wheeled tractors

Table 2
The American classification of skin runs based on slope angles.

Green circle runs	Easiest	6–25% slopes
Blue square runs	Intermediate	25–40% slopes
Black diamond runs	Difficult	>40% slopes
Double black diamond runs	Expert	Very steep + jumps, etc.

- Some landforms have spiritual, historical or cultural associations. Examples include the many mountains held sacred by local populations, including Uluru in Australia, Fujiyama in Japan and T'ai Shan and Mount Wutai in China. Rivers, caves, waterfalls and other landforms also sometimes have religious significance. In terms of historical associations, churches have often been built on high points in the landscape while castles have usually utilised particularly steep -sided hills as excellent defensive sites. Many landforms have been explained by legends or folklore including the Devil's Towner in Wyoming, USA whose columnar jointing is alternatively explained as the result of scratching by a giant bear. Legends like this give added value to these landforms.
- Artists, poets, musicians and authors are often inspired by the landscapes around them to create great works. The best example is probably The *Hebrides Overture*, otherwise known as *Fingal's Cave*, by the German composer Felix Mendelssohn who wrote it following a visit to the Isle of Staffa off the west coast of Scotland.

4.2. Geological materials

The societal benefits of geological materials are all around us:

- Although some wood and other organic materials are used in the construction of buildings, the vast majority rely on materials extracted from the Earth's crust. The following are some examples:
  - *Stone* Early humans lived in rock caves but today stone, in the form of quarried blocks, rough or cut, is used in wall construction, as internal or external facing slabs (cladding), or as floor tiles, paving or roofing materials. A huge variety of stone is used. Traditionally this reflected the local geology, and although many local materials are still used, there has been an increasing globalisation of decorative stone slabs and tiles for cladding, flooring or other purposes. Slate is a commonly used roofing material whereas sandstones and granites have in the past been commonly used in load bearing wall construction, though today concrete and steel are more generally used in new buildings in the world's cities. The Romans used different coloured stones to produce mosaic pictures, and today rock diversity is often used to create patterns in paving materials (see Fig. 3).
  - *Aggregates* These are collections of rock particles produced either from natural processes of deposition or by crushing of rock. These materials are normally sorted into different size fractions which then have different active uses. Sand is used in the production of cement and concrete, in road construction, for beach replenishment and as a fill material. It has even been used to construct or enlarge islands, e.g. in Dubai and the South China Sea. There is growing concern about the shortage of sand sources and about the extraction of sand from beaches, river channels, the seabed and elsewhere in several parts of the world (e.g. Torres, Brandt, Lear, & Liu, 2017), though Bendixen et al. (2019) have suggested that sand being deposited from Greenland's melting glaciers could be a significant future source. Gravel is also used as a fill material but is also combined

Fig. 3. Basalt and limestone pavement patterns: Copacabana Beach, Rio de Janeiro, Brazil.

with cement in the production of concrete. The most suitable rock types for this are hard, quartz-rich lithologies such as quartzites or durable sandstones.
- *Limestone* Is the main constituent of cement, with clay or ash and gypsum making up the remaining 25%. Cement is used in the production of concrete or as floor screed or wall render.
- *Clay* is used in the production of bricks and tiles, with sand also added to provide a more open texture.
- *Gypsum* is the main constituent of plaster used as a render on walls and ceilings, including its use in the manufacture of plasterboard.
- *Glass sand* is a pure type of sand with low proportions of clay, iron and other impurities, though it is common for these to be removed by washing, sieving etc.

Fig. 4 is a deconstruction of a small building illustrating the variety of building materials used.

• A huge variety of industrial and metallic minerals are used in a staggering number of ways by our modern societies. Nothing demonstrates this diversity better than the smartphone, which contains over three-quarters of the non-radioactive elements in the Periodic Table, all of which have been extracted from the Earth's crust (Dartnell, 2018; Rohrig, 2015). Each element plays a particular role in the phone. For example, indium tin oxide conducts electricity and is used as a transparent film on the screen allowing it to function as a touch screen. The screen also contains a variety of Rare Earth Elements used to produce different screen colours. Most smartphone batteries are composed of lithium cobalt oxide and graphite, with aluminium as the battery casing. Elements in the electronics include copper, gold, silver, tantalum, nickel, silicon, tin and several Rare Earth Elements.

But it is not just smartphones that involve a huge range of industrial and metallic minerals. Think of the metallic materials we use in our homes from domestic appliances to lighting and heating systems. Then outside, we have the equipment in our factories and hospitals, our vehicles and our transportation networks, and our use of phosphates and potash as agricultural fertilizers. Modern societies simply could not exist without this geodiversity of geological materials.

• *Gemstones* are exploited for their aesthetic value but are also used as abrasives. There are around 200 gemstone types but also diversity within each type. For example, quartz gemstones include amethyst, rock crystal, milky, smoky and rose quartz, chalcedony, cornelian, onyx, jasper and agate, but each of these itself exhibits a range of forms and colours.
• *Energy sources* include coal, peat, oil, natural gas and uranium, while renewable sources of energy from the physical world include geothermal, hydroelectric, wind, wave and tidal power.

4.3. Physical processes

Physical processes are important as they create the topographies and geological materials discussed above and play many other roles that benefit society:

• For example, the atmosphere and oceans play crucial roles in regulating the temperatures on the planet. Their global circulations redistribute heat away from the tropics and towards the poles, without which tropical areas would get progressively hotter while the poles would become steadily colder.

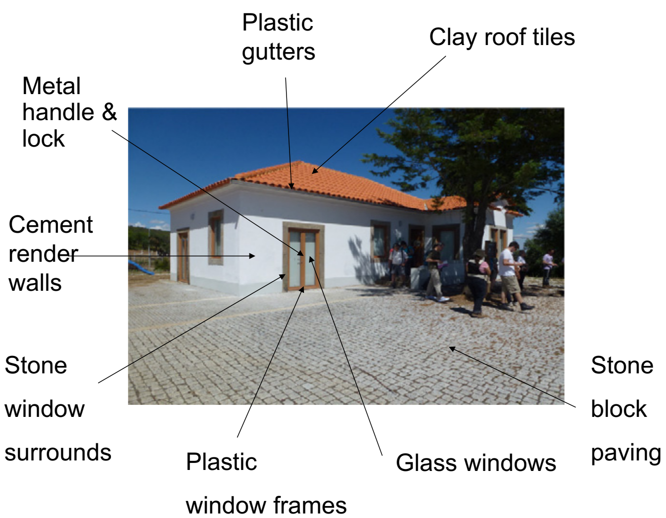

Fig. 4. Deconstruction of a small building in Portugal showing the diversity of geological materials used. (Modified from Gray (2018a)).

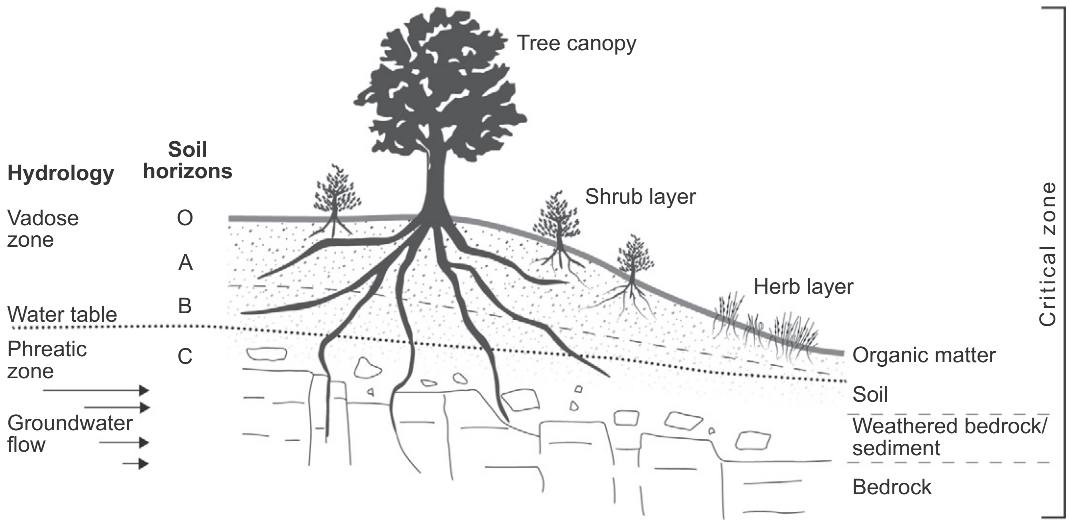

Fig. 5. The "critical zone".
(From Gray (2018b) with permission of Elsevier).

- The hydrological cycle is important in circulating water between oceans, atmosphere and land, including through continental ice sheets and glaciers. Rivers and streams are effective in draining water from the land surface. Other cycles, including the carbon, nitrogen, phosphorous and sulfur cycles, are important in allowing elements to flow between biotic and abiotic parts of ecosystems.
- Rock, sediment and soil perform important roles in filtering and attenuating pollution from infiltrating waters and thus in maintaining groundwater quality. The attenuation can occur by, for example, adsorption or ion-exchange. The effectiveness will depend on the nature and thickness of the rock, sediment or soil above the water table. For example, a thin cover of fractured rock will be much less effective than a thick cover of clay in protecting groundwater from agrichemical pollution on the surface.
- Infiltration of water into soils, sediments and rock also helps to reduce flooding by reducing surface runoff and delaying the delivery of rainwater to river channels.
- Processes of erosion, transportation and deposition constitute a rock cycle that is responsible for delivering the quantities of sand and gravel aggregates referred to above.
- Other important surface processes are chemical and mechanical weathering, which change the structure and/or composition of the parent material to create a regolith. This in turn is colonised by plants and animals so that organic material is added giving soil an important role as a link between the animate and inanimate worlds. Soil, of course, is vital to society in providing a growing medium for crops and this role has led to the concept of regolith and soil being a key part of the "critical zone" (Fig. 5) extending from the base of groundwater flow to the top of the tree canopy (Guo & Lin, 2016).
- Some plants and animals also rely on surface processes. For example, the chinstrap penguins on Zovodovski Island in Antarctica benefit from the high geothermal heat flux thus helping penguin egg incubation.

5. Geoheritage and geoconservation for society

Point 21 of Fig. 1 is related to Earth history. Geoheritage is defined as those parts of geodiversity that are important for reconstructing Earth history (Sharples, 1993). The case for society conserving geoheritage sites is similar to that for conserving historic or archaeological sites. But rather than conserving the evidence for reconstructing human history, we are dealing here with the history and evolution of the planet. There is a strong case for conserving the important sites that either have allowed, or have the potential to allow, scientists to reconstruct Earth history and the evolution of life on the planet. And since humans have evolved during geological time and by natural selection from ancestor species, it follows that human history is part of Earth history. So, an important reason for conserving geoheritage is that it gives us an understanding of the history of the planet and our place in it.

Many important sites have been and are being damaged or destroyed, particularly in the developing world, but in the developed countries too, through a lack of knowledge about geodiversity and geoheritage. This makes it important to implement geoconservation measures (Prosser, Diaz-Martinez, & Larwood, 2018). Further important reasons for protecting geoheritage sites are to retain these for educational field trips and for the training of future geologists.

There are two main international programmes of relevance to geoconservation – World Heritage Sites and Global Geoparks. Both are promoted by UNESCO as being closely beneficial to society. For example, the *World Heritage Convention* (WHC), adopted by UNESCO on 16 November 1972, recognises that "parts of the cultural or natural heritage are of outstanding interest and therefore need to be preserved as part of the world heritage of mankind as a whole". It therefore asserts that conservation benefits society through preserving features of current aesthetic or scientific importance or inherited from the past. This is further underlined by the *Operational Guidelines for the Implementation of the World Heritage Convention* (12 July 2017) which state (Para 4) that:

> "The cultural and natural heritage is among the priceless and irreplaceable assets, not only of each nation, but of humanity as a whole. The loss, through deterioration or disappearance, of any of these most prized assets constitutes an impoverishment of the heritage of all the peoples of the world. Parts of that heritage, because of their exceptional qualities, can be considered to be of 'Outstanding Universal Value' and as such worthy of special protection against the dangers which increasingly threaten them".

And further states at Para 49 that:

> "Outstanding Universal Value means cultural and/or natural significance which is so exceptional as to transcend national boundaries and to be of common importance for present and future generations of all humanity. As such, the permanent protection of this heritage is of the highest importance to the international community as a whole". There is no question then that UNESCO sees World Heritage Sites as essential to society and this is supported by other sources (e.g. Dingwall, Weighell, & Badman, 2005). There are 6 cultural and 4 natural criteria, at least one of which must apply to nominated sites. As of October 2019, there were 93 World Heritage Sites inscribed under criterion viii, which is the geological one defined in the *Operational Guidelines* as "representing major stages of earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features".

One example of these sites is the South China Karst. This is a serial World Heritage Site comprising seven karst clusters in four of China's Provinces and inscribed in two phases in 2007 and 2014. The clusters demonstrate a 700 km long, north-south transition from the 2000 m high Yunnan-Guangxi Plateau to the lowland plains of the eastern Guangxi basin. The sites contain the world's finest examples of humid tropical and subtropical tower and cone karst. Fig. 6 shows an attempt to appeal to national or provincial pride in order to help protect the area, and its use of the phrase "our homeland" is a further indication that conservation is of benefit to society.

UNESCO Global Geoparks (UGGps) have three main aims – conservation of geoheritage, geological education for the public, and sustainable economic development mainly through geotourism. The *Operational Guidelines for UNESCO Global Geoparks* make it clear that a fundamental requirement of UGGPs is that they are rooted in local communities. Thus Para 3(v) states that:

> "UNESCO Global Geoparks should actively involve local communities and indigenous peoples as key stakeholders in the Geopark. In partnership with local communities, a co-management plan needs to be drafted and implemented that provides for the social and economic needs of local populations, protects the landscape in which they live and conserves their cultural identity".

Gray (2013, p. 239) concluded that "the aim is to allow local communities to take ownership of their geological and other heritage by protecting it, promoting it and, by doing so, gaining some sustainable economic benefit from it". In addition, Henriques and Brilha (2017) see UGGps as contributing to global understanding and sustainability. As of October 2019, there were 147 UGGPs in 50

Fig. 6. Notice at the entrance to the Huanjiang section of the South China Karst World Heritage Site.

countries. One example is the Arouca UGGp in northern Portugal which has a Middle Ordovician site (Canelas) where some of the largest trilobites (up to 90 cm) and trilobite clusters in the world have been found. The area of the geopark is around 330 km^2 and corresponds exactly to the administrative borders of the Arouca Municipality with about 25,000 inhabitants. A non-profit association composed of public and private institutions with local and regional relevance manages the geopark. This Arouca Geopark Association (AGA) was created just for this purpose, under the leadership of the local municipality. A Scientific Advisory Board with experts from different Portuguese universities supports the science policy and AGA activities. Thus, geopark management is deeply embedded in the local community.

Neither WHS nor UGGp status gives legal protection to geosites. This is the responsibility of the countries, or sometimes provinces/regions, in which they lie. However, in order to obtain WHS status applying state parties must indicate what legal protection is in place to help conserve the sites, and for UGGps applicants are expected to describe the current status in terms of protection of geological sites within the geopark.

All UGGps and many World Heritage Sites go to significant efforts to attract visitors and explain geological issues and the local geology to them. This is done, for example, through visitor centres and/or local museums, by visitor panels, through educational programmes, displays and activities, by books, leaflets and other publications, by geotrails, through websites and apps, and by festivals and events. All these activities indicate a strong desire to involve and immerse the public in the local geology and geomorphology and in the geosciences generally, and a significant willingness of the public to visit these special places, bringing significant benefits (e.g. Gabriel et al., 2018). For example, the Grand Canyon National Park and WHS (Fig. 7) receives almost 5 million visitors per year, while the Cliffs of Mohar, part of an Irish UGGp, received over 1.5 million visitors in 2018. An important point is that all these geoconservation activities generate significant economic benefits to local communities. A UK report on the *Wider Value of UNESCO to the UK, 2012–2013*, found that the 7 Global Geoparks in the UK provided a net estimated annual financial benefit of £18.84 million (UKNCU, 2013). All around the world, geotourism is thriving, and not just in these internationally important places.

National nature conservation sites are also usually promoted as being beneficial to society. An important case study in this respect occurred at Birling Gap, a designated Site of Special Scientific Interest (SSSI) on the south coast of England. Here Chalk cliffs (overlain by periglacial sediments) are being eroded by the sea and causing the destruction of cottages on the clifftop (Fig. 8). Residents, unable to persuade the authorities to protect their properties by building sea defences, submitted their own planning application for a revetment of boulders along the base of the cliffs. This application was refused by the local planning authority, but the residents appealed this decision and a public inquiry was held in 2000. At this inquiry the refusal was supported by English Nature, the government's then advisors on nature conservation, who argued that continued erosion of the cliffs was important to conserve the spectacular local coastal scenery, conserve the exposures of Chalk and periglacial sediments, and maintain the local supply of beach material thus protecting the rest of the cliffline. The residents argued that protection of their properties was more important than the scientific importance of the site. In confirming refusal of the proposals, the inquiry inspector stated that they would harm the scenic and scientific quality of the area and its conservation. He made the important point that it is not just scientists who value the SSSI since the legislation to protect it is passed by elected representatives and is therefore authorized by society as a whole (Prosser, 2001).

A few years later a similar case arose at Easton Bavents, an SSSI on the east coast of England. Here a local resident took matters into his own hands by building his own unauthorized sea defences through importing thousands of tonnes of waste soil deposited against the cliffline, which here is composed of Quaternary sediments. In the legal procedures that followed, the resident questioned whether allowing the cliffs to continue to erode should be considered as conservation. However, a High Court judge concluded that “one would have thought that allowing natural processes to take their course, and not preventing or impeding them by artificial means from doing so, would be a well-recognized conservation technique in

Fig. 7. Geotourists at the Grand Canyon National Park and World Heritage Site, USA.

Fig. 8. The eroding coastal cliffs at Birling Gap, southern England.

the field of nature conservation". Thus, the English courts have also supported society's conservation legislation (Prosser, 2011).

In 2016, the website of the South African National Parks (SANParks) and of individual park maps, were titled as "Your Natural Heritage "(Fig. 9) thus emphasizing that these protected areas belong to the public as a whole rather than to any authority. At the West Coast Fossil Park, about 150 km north of Cape Town, an important Mio-Pliocene vertebrate site has been discovered in a disused phosphate pit. A new Visitor Centre was opened in 2018 funded by the South African National Lottery to the tune of 67million Rand (= c. $5 million), thus illustrating the South African public's support for protected area conservation.

6. Conclusions

Since humans first started using stone tools hundreds of thousands of years ago, there has been a steady increase in the human use of geological materials. Today, it is no exaggeration to say that our modern society could not exist without the utilization of the Earth's geological resources. Nothing illustrates this better than the large number of geological materials that go into smartphones. But this is only one example of how society benefits from living on a geodiverse planet. People not only value their material world but also benefit from topographic variety, landscape aesthetics, physical processes and the way in which geological sites reveal the history of the planet and evolution of life on it. High visitor numbers to World Heritage Sites, Global Geoparks, and national geoconservation sites demonstrate a strong public appetite for appreciating their spectacular physical surroundings, and provide a significant boost to local economies.

Fig. 9. Webpage of the South Africa National Parks in 2016.

Declaration of competing interest

None.

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