

Review

# Geoheritage and Cultural Heritage—A Review of Recurrent and Interlinked Themes

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**Abstract:** Relationships between geoheritage and cultural heritage are being increasingly explored and have become one of the mainstreams within studies of geoheritage and geodiversity. In this review paper, we identify the main and secondary themes at the geoheritage—cultural heritage interface and provide examples of specific topics and approaches. These themes include added cultural value to geoheritage sites, geoheritage in urban spaces, cultural landscapes, and the contribution of geoheritage to their identity, mining and quarrying heritage, linkages with natural disasters, history of science, and art. Intangible cultural heritage is also reviewed in the geoheritage context. In the closing part of the paper, various classifications of geoheritage—cultural heritage linkages are proposed, although it is concluded that themes and fields of inquiry are overlapping and interlinked, rendering one classification system not very feasible. Instead, a mind map to show these diverse connections is offered. The paper closes with recommendations for future studies, arising from this review and the identification of research gaps and under-researched areas.

**Keywords:** urban geoheritage; building stone; cultural landscapes; mining; quarrying; geotourism; UNESCO World Heritage; natural disasters



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## 1. Introduction

Even though the term “geoheritage” tends to emphasize the rock, fossil and landform record created by natural processes during protracted intervals of geological evolution, it was never disassociated from cultural heritage and some definition proposals include cultural significance [1]. Relationships between geoheritage and cultural heritage are multiple: spatial, conceptual, causal, and thematic [2,3]. Likewise, part of geoconservation is located at the interface with cultural heritage, as the introduction of certain conservation measures may necessitate a good understanding of the local cultural context, including the intangible heritage of indigenous societies [4], whereas on the other hand, preservation of built-up cultural heritage requires adequate consideration of building-stone heritage. Finally, geoparks—as means of transferring knowledge of geosciences to the society and increasing awareness of geoheritage—strongly emphasize the ABC concept that highlights linkages between abiotic, biotic and cultural components [5]. In this review, we outline the multiple linkages between geoheritage and cultural heritage, identifying the main themes that explore this interface and provide selected examples, mainly taken from publications published in the last decade or so.

This review does not pretend to be exhaustive in the coverage of recent literature, which is growing at an unprecedented rate and hence, difficult to follow. Likewise, we do not employ a bibliometric and text-mining approach, even though we acknowledge it can be an interesting step towards recognition of thematic preferences among researchers involved in geoheritage issues. In our view, the main contribution of this paper is the identification of the diversity of topics and approaches. In doing so, we build upon the work of Reynard and Giusti [3], who listed three main questions pertinent to the cultural

value of geoh heritage: (1) how geological processes and geoh heritage affect culture, (2) how culture affects geoh heritage perception and management, and (3) how culture and geological heritage are integrated. Although the themes presented in this paper can be subsumed under these three lines of inquiry, they are sufficiently broad and multifaceted to deserve more systematic presentation.

## 2. Geoh heritage Sites of Additional Cultural Significance

It has long been recognized that localities appreciated by geoscientists for their geoh heritage values may also carry significant cultural values, with or without causal connection between the two (Figure 1). Reasons for cultural significance are varied, both intangible and tangible, and may include spiritual (religious) importance, connection with local legends, famous personalities and historical events such as battles or meetings, occurrence of architectural heritage, typically defensive structures, shrines and temples, tombs, or even entire settlements, the presence of rock art, and former mining grounds.



**Figure 1.** Geomorphosites with additional cultural values. (a) cinder cone of Zebín in the Bohemian Paradise UNESCO Global Geopark is an important geosite, with the medieval church at the foot (right) and a baroque chapel on the top, (b) conglomerate rock city of Belogradchik, Bulgaria, with remnants of the Kaleto fortress incorporated into it, (c) a large erratic boulder in central Poland (Budziejewko village), associated with various local legends, (d) Solfatara in Pozzuoli, Italy, is a world-renowned volcanic geosite, visited and used for therapeutic reasons since antiquity (all photographs by the authors).

Landforms, rather than geological outcrops, represent most of geoh heritage sites with these associations, which is understandable given their often prominent position within a regional landscape. Thus, these geoh heritage sites may be also considered as geomorphosites [6]. Typical geomorphosites of this kind are distinctive terrain elevations (volcanoes and volcanic necks, inselbergs, dome-shaped hills, mesas, solitary pinnacles), crags and tors, cliff lines, both coastal and inland, canyons, gorges, and necks of entrenched

meanders. Relevant smaller landforms include erratic boulders and their clusters, curiously shaped weathering features, rock shelters, gullies, and dolines. Caves may also belong to geoheritage of mixed significance [7], if they contain archaeological remains, examples of rock art (paintings, petroglyphs), or were used as hideouts or hermitage sites.

The dual, globally outstanding value, involving both geoheritage and cultural heritage, is demonstrated at UNESCO World Heritage mixed properties. Their total number is 39, as of early 2022 ([www.unesco.org](http://www.unesco.org); accessed on 22 January 2022), although not all of them are recognized for geoheritage. Among sites recently presented are the travertine depositional features associated with an ancient town of Hierapolis in Pamukkale, Turkey [8], and conglomerate towers crowned by Orthodox Christian monasteries at Meteora in Greece [9,10], whereas the great sandstone sceneries of Tassill n'Ajjer (Algeria) and Ennedi (Chad) that include impressive rock art of outstanding value are still waiting for proper presentation of their geoheritage.

Some of the recently published studies emphasised spiritual [11] and military use of caves [12], their importance for archaeology and human history [13], the use of natural configuration of rock landforms to insert defensive structures such as castles and fortresses [14], and incorporation of modern architecture into natural rock-cut scenery [15]. Large erratic boulders in the formerly glaciated European lowlands areas have often acquired special cultural significance, being associated with pre-Christian cults, beliefs in supernatural powers, legendary or historical events [16,17]. These associations are also reflected in their names, containing references to evil spirits or saints. Huge granite boulders in granite denudational landscapes, especially if associated with intriguing microrelief (circular weathering pits, karren) may also bear similar associations, for instance in the Waldviertel area of Austria [18]. Multiple connections between volcanic phenomena and related landforms and diverse human activities over centuries were presented for the Campi Flegrei area in southern Italy [19], whereas in the Swabian Alb, southern Germany, various karstic sites (caves, tufa cascades, springs) have strong associations with local cultural heritage [20,21].

### 3. Urban Geoheritage and Heritage Stones

Exploration of geoheritage in an urban context is among the most frequently addressed themes at the geoheritage/cultural heritage interface. It is close to urban geomorphology on the one hand, which examines how landform patterns influence location and growth of towns and cities [22], but crosscuts the heritage stone issues, ranging from conservation challenges at historical monuments to the identity of a city due to preferential use of a certain kind of building stone. Thus, specific subjects also vary in the spatial scale of inquiry, from a singular building to the whole-city layout and appearance (Figure 2).

Some towns and cities are presented as examples of how urban planning, often going back to medieval times or even beyond, was adjusted to natural topography and spatial domains of ongoing geomorphic process, thereby enhancing local geoheritage rather than erasing it [23–25]. In Rio de Janeiro, this symbiosis between superb granite geomorphology, with its numerous steep-sided domes [26,27], and specific urban design and culture was even emphasised in the justification of outstanding universal value, decisive for the city's inscription on the UNESCO World Heritage list as an urban cultural landscape (Figure 2a).

However, accelerated urban growth coupled with increasing engineering abilities has led to the situation that natural landform features no longer control pathways of urban development, but may have been eliminated if that was considered necessary. The respective engineering solutions include valley filling, channel relocation, slope grading and hilltop trimming, with the common denominator being the ultimate disappearance of a landform. In specific places, these disappeared landforms may have been of geoheritage value. Recently reviewed examples include Rome [28] and Genoa in Italy [29], Lausanne in Switzerland [30], Mexico City [31], Perugia [32], Toruń in Poland [33], Brno in the Czech Republic [34], and Auckland in New Zealand [35].



**Figure 2.** Examples of urban geoheritage of different kinds and scale. (a) the city of Rio de Janeiro developed amidst large granite-gneiss domes, (b) Tiberina Island in the centre of Rome is a much altered natural gravel bar of the river Tiber, (c) a romanescque cathedral in Modena, Italy, built of various building stones, (d) Parc des Buttes-Chaumont—an old gypsum quarry in the centre of Paris, converted into a municipal park (all photographs by the authors).

Despite the inevitable loss of geodiversity and geoheritage due to urbanization, or perhaps in response to it, a voluminous literature concerns recognition of geoheritage sites within urban space. Some publications deal with classic localities, appreciated for more than a century, such as the giant glacial potholes in Luzern, Switzerland [36], but there is an increasing trend to present less evident cities and towns to an international audience. For some of these, local language literature may have been available earlier, but broadly accessible sources were missing. Places of recent interest include São Paulo [37], Lisbon [38,39], Poznań [40], Segovia [41], Oslo [42], Khorramabad in Iran [43], Brno [34,44], Ljubljana in Slovenia [45], and Zagreb in Croatia [46]. Apart from large cities, small towns are also occasionally evaluated in this context, such as Pruszków in Poland [47]. However, in many of these cases the assessment of urban geoheritage is limited to sites of geological interest, mainly natural or artificial bedrock outcrops, whereas geomorphological heritage and viewing points allowing for examination of geomorphological scenery are considered less often. This imbalance may be partly related to the intensity of urban development but may also reflect specific interests of particular authors. Thus, the diversity of urban geoheritage was presented by Pica et al. [28] for the heart of Rome (ancient Rome), where geomorphological, hydrological, and stratigraphical geosites were identified (Figure 2b), whereas in Mexico City, attention was directed to the remnants of the lake, the use of ornamental stones, and old lava flows, the latter encroaching onto a pre-Hispanic ceremonial centre at Cuicuilco, with its partly buried round pyramid [31]. In Segovia, as many as 94 potential geosites belonging to 16 thematic categories were documented [41], whereas in Brno, 89 localities were analysed in terms of scientific (geoheritage, geodiversity) and added values, the latter including cultural associations [48].

A theme in its own right is heritage stone, usually analysed in an urban context (Figure 2c), even though its use in vernacular architecture is also addressed [38,49–60]. De Wever et al. [50] reviewed the significance of geosites and heritage stones in a more general way, providing numerous examples from European cities of how background geological knowledge may be used to design rock-focused geotrails, leading visitors to famous historical buildings erected from characteristic stones and to the very sites of stone extraction, that is ancient quarries now located within city limits or just outside. These examples include the towns of Salamanca in Spain, Bath in England and Paris, where an old gypsum quarry at Buttes-Chaumont was converted into a large park (Figure 2d). Some publications are deliberately focused on one or two rock types, most used in a region. In the Segovia province in Spain, rock colour determines the visual appearance of villages, named as ‘red hamlets’ (*pueblos negros*) and ‘black hamlets’ (*pueblos rojos*). These differences reflect the use of traditional building materials, Miocene red gossan breccias and Ordovician-Silurian black slates, respectively [61]. Further examples include the use of Arrábida Breccia in manueline-style buildings in central Portugal [62], Red Ereño limestone in the Basque Country, Spain [63], and green phyllite used for roofing in Lugo in Galicia, Spain [64]. This geoheritage-oriented approach to building heritage is not limited to Europe. Numerous recent papers have documented heritage stone use in India, including basalt [65], marble [66,67], sandstone in Rajasthan province [68], limestone [69], slate [70] and quartzite [71]. Other studies have been focused on particular regions rather than specific building stones, as exemplified by a recent thorough study of historic stones used in construction of churches and chapels in West Sussex, England [72], examination of geological foundations of Japanese castles [73], or inclusion of more than 30 historical structures into a comprehensive geoheritage and geodiversity assessment in the Sudetic Foreland Geopark, Poland [74]. It is also observed that building stones, as well as pavement tiles, may contain fossils and hence, are suitable for palaeontological education for the general public [75–78]. Valentino et al. [79] described special mobile applications designed to help recognizing rock types used in architecture. The range of heritage stone themes was recently expanded by consideration of lighthouses [80] and cemeteries, where various rock types are used as tombstones and in sepulchral art. A notion of ‘cemeterial geotourism’ was recently proposed [81,82].

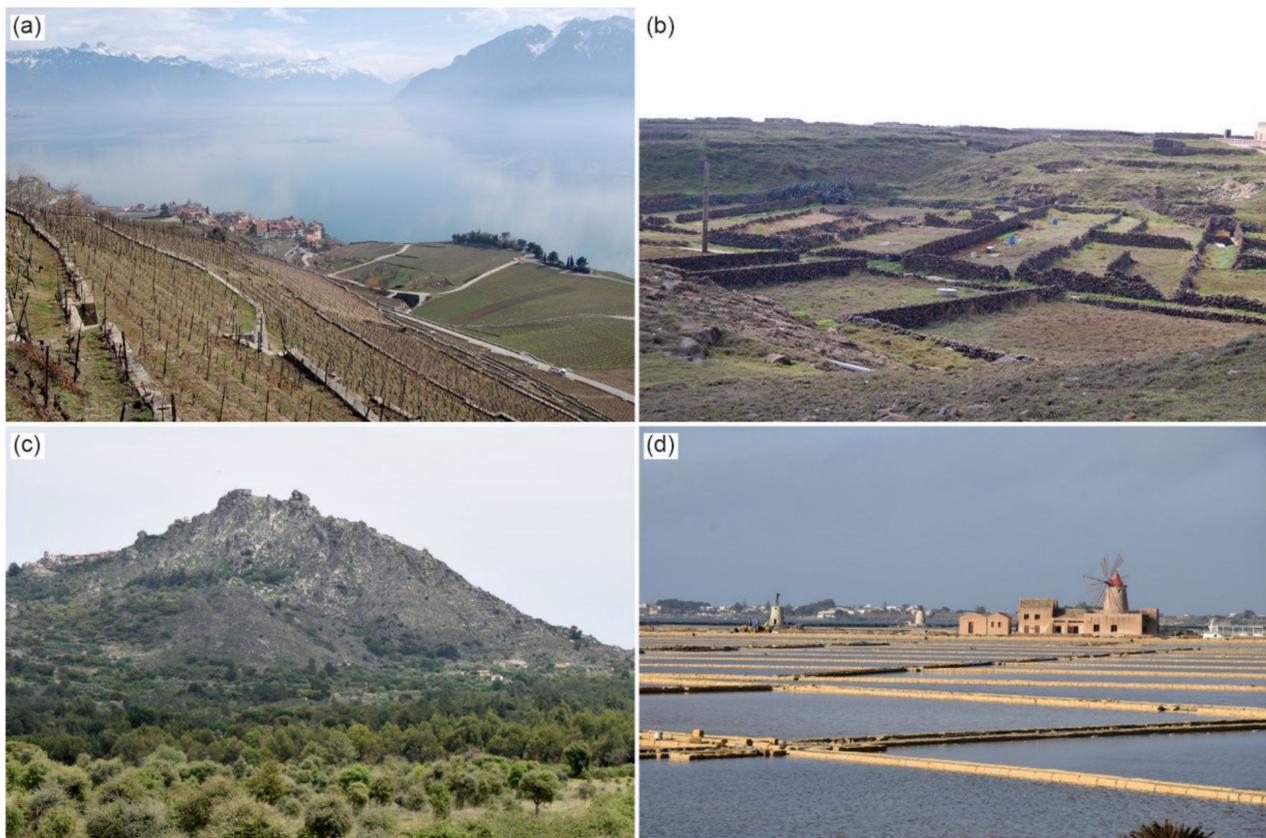
Geosites other than rock outcrops, landforms and buildings are seldom addressed. However, the significance of hydrological sites, mainly springs and ancient wells, has been realized in Rome [28], Perugia [83], and Lisbon [84].

#### 4. Cultural Landscapes

The relevance of geoheritage to cultural landscapes and various relationships between the two have been recently comprehensively reviewed by Gordon [2]. The contribution of abiotic components is very diverse, ranging from crucial underpinning of the landscape [85,86], evident in its rock- and/or landform-controlled appearance, to incorporation of minor and not necessarily very significant elements into a landscape that is dominated by anthropic elements, with all possible intermediate situations. Consequently, the spatial extent and specific characteristics of cultural landscapes twinned with geoheritage vary too (Figure 3). Although a complete typology is difficult to propose, notable examples include: (a) rugged countryside adjusted to become an agricultural area through an introduction of terracing and stone walls, (b) romantic parks and gardens built around distinctive natural landforms, (c) rural settlements constructed with the pervasive use of distinctive stone types, (d) certain mineral extraction areas, where technology required modification of natural relief (e.g., salt extraction ponds—salinas), (e) adjustments of natural topography to better serve defensive purposes, (f) rugged rock landscape, as settings of monastic complexes and other sites of spiritual significance, and (g) cave dwellings incorporated into natural rock cliffs. Landscapes dominated by the legacy of mining may be also considered as cultural landscapes, even though alteration of the natural environment was usually quite substantial. This topic, closely linked with mining heritage issues, is presented more thor-

oughly in Section 5. Less evident and rarely explored in geoheritage context are land-use histories related to specific soils, giving rise to ‘soilsapes’ [87].

Cultural landscapes associated with agricultural production are perhaps best exemplified by rice fields and vineyards, the latter often located on steep hillsides of favourable soil and topoclimatic characteristics, significantly modified through terracing. As of 2021, 14 wine-producing regions in several European countries (Portugal, Spain, France, Switzerland, Italy, Germany) were listed as UNESCO World Heritage properties, recognized as cultural landscapes of outstanding universal value [88,89]. The analysis of documents demonstrated that the underpinning role of geology and landforms is increasingly recognized and recent nomination files for World Heritage give due attention to the abiotic factors [89]. An excellent example of very tight links between geology, landforms and land use is provided by the vineyards of Lavaux at Lake Geneva in Switzerland, inscribed in 2007 [90]. Here stepped hillsides are natural landforms and reflect repeating appearance of stronger conglomerates and less resistant sandstones and mudstones in the vertical geological profile. The former support mid-slope cliffs, whereas the latter underlie slope sections of lower inclination, developed as vineyard plots (Figure 3a). The terraced slopes of the famous Alto Douro wine district in Portugal is another recently presented case of close relationships between abiotic factors and wine culture [91]. Winescapes involving geoheritage value are not limited to World Heritage properties and famous wine regions but occur in other regions too [92–95].



**Figure 3.** Cultural landscapes illustrating various connections with abiotic nature. (a) terraced slopes of Lavaux Vineyards in Switzerland, with the glacial trough of Lake Geneva in the background, (b) stone walls built of local basalt and pieces of corals are part of endangered cultural heritage of Penghu Islands, Taiwan, (c) granite inselberg of Monsanto, Portugal, with the village built almost exclusively from local granite (left) and castle ruins on the hilltop, (d) salt pans near Trapani, Sicily, Italy (all photographs by the authors).

The geoheritage context of stone-walled countryside sceneries is represented by the use of local stone to build the walls (Figure 3b), where availability of stone of specific shapes and dimensions as well as their other properties dictated construction technologies applied in specific localities [96–98]. Consequent to the realization that stone walls are part of combined geo-cultural heritage are studies of their degradation after abandonment, which is considered as a loss of value [99,100].

Incorporation of natural geomorphic and hydrological features into park and garden layouts was part of the 19th century romantic concept of ‘tamed wilderness’, implemented in Central and Western Europe. Using a specific example from an intramontane basin in the Sudetes it was shown how denudational granite landforms such as domes, tors, boulder piles, open and roofed clefts, overhangs, and minor weathering features became integral parts of landscape parks designed around royal and aristocratic residences [101].

Stone type used for construction of houses, street paving, plot-bounding walls and small architecture was long recognized as a factor defining the identity of rural settlements. This connection between abiotic and cultural spheres is often emphasized in European Geoparks, exemplified by heritage stone villages such as Monsanto in Naturtejo Geopark in Portugal, almost perfectly blended with the granite outcrops on the slopes of this impressive inselberg (Figure 3c), slate villages in the region of Valdeorras, Galicia, in Spain [102], or heritage villages in the Courel Mountains UNESCO Global Geopark, also in Spain [103].

Adaptation of existing caves, rock shelters and overhangs to serve as dwelling places, storage rooms and shrines has a long tradition in various parts of the world, especially where rock is simultaneously soft enough to allow for excavations, but sufficiently strong not to suffer from immediate wall or roof collapse. Tuffs and certain variants of sandstones fulfil these requirements and host extensive underground spaces used by people either in the past or, less commonly, until now. The archetypal example is the rock landscape of central Cappadocia, with its underground cities, rock-hewn churches, houses and pigeonholes [104], whereas multiple uses of natural and excavated hollows in sandstones were presented in the pictorial atlas of sandstone landforms of Czechia [105]. In limestone, in turn, natural caves were ready-to-use places for habitation, as documented from many countries worldwide, particularly from the Mediterranean realm. Further examples of cave dwellings were recently provided from the Basilicata region and Amendolara in southern Italy [106,107], Matmata in Tunisia [108], Vardzia and Uplistsikhe in Georgia [109], and from the Mekong Delta in south-east Asia [11].

A small-scale example of adaptation of natural landforms to serve economic purposes is offered by rocky shore platforms, modified into patterns of interconnected shallow pans to allow for salt harvesting [110–112]. Locally, salt pans were also developed in inland sites (Figure 3d) [113].

Defensive cultural landscapes may take different shapes and exploit various natural features. In the coastal context, Schembri and Spiteri [114] examined the pattern of drowned valleys (rias) on the north-eastern coast of Malta and how it underpinned the long-term strategy to fortify the city of Valletta and adjacent settlements, then the headquarters of the St. John’s Order. Another great example is provided by Hadrian’s Wall in northern England, where the 2nd century AD fortifications from the times of the Roman Empire were erected on the top of a long dolerite ridge, which is a distinctive rock-controlled landform and regional landmark [115]. In a similar vein, the association of the walled city of Luxembourg with the natural scenery of sandstone cliffs and canyons was examined [116]. All these three localities are UNESCO World Heritage cultural properties. Even though the geological underpinnings themselves are not considered of outstanding universal value, they were crucial for the appearance and significance of these defensive facilities.

Human perception of some rugged rock landscapes as locations of spiritual significance, present in various cultures and religions across the world, resulted in visitations, erection of temples and hermitages, and eventually transformation of the entire physical landscape, which however retained the main scenery values. The most impressive examples have the status of UNESCO World Heritage properties, such as Meteora in Greece, where

monasteries were built atop rock pillars built of conglomerates [10]. Many impressive rock landscapes in China, valued for their geology and geomorphology, are closely associated with Taoism and Buddhism, as reflected in the presence of temples, shrines, tombs, sacred wells etc., connected by an intricate network of paths and staircases, with accompanying minor monuments and statues [117]. The theme of sacred meaning of natural landforms, present in different cultural environments of the world, and how they are used by people nowadays, was comprehensively reviewed by Kiernan [118].

## 5. Mining and Quarrying Heritage

The use of natural mineral resources is another frequently explored theme at the interface of geoheritage and cultural heritage. Two interlinked aspects may be distinguished within these inquiries, related to on-site exploitation and testified by mines, quarries and other sites of extraction, as well as to the fate of rock blocks and other materials retrieved from sites of exploitation, including means of their transportation to destination sites. The latter bridges the gap between mining heritage and heritage stone, covered in Section 3.

Within this broad theme, on the one hand, it is the rock itself and its various properties that are of interest. An important point is that quarries and mines often offer excellent opportunities to examine rock complexes in three dimensions, over areas usually larger than natural outcrops [119–121]. Hence, geologists have a long-standing interest in monitoring quarry operations, to update three-dimensional views of rock masses and all inherent structures. It is also not surprising that abandoned quarries (and occasionally working ones as well) are listed as geosites within regional or national inventories [122,123]. On the other hand, more relevant to this paper, quarrying and mining are parts of cultural heritage, with tangible evidence not limited to the quarry faces/mine adits themselves, but extended over processing plants, mine buildings, transportation routes, waste heaps, collapse hollows above ancient exploitation chambers, etc. [124–126]. Quarry layouts and mine galleries reflect engineering and working skills of quarrymen and miners and were often carefully adjusted to local geological conditions to minimize physical efforts and expenditures and to maximize effectiveness [127,128]. Mining and mining-related heritage is also presented and analysed in the wider spatial context, as a key factor contributing to the identity of a region, linking to the theme of cultural landscapes addressed more comprehensively in Section 4. Selected examples include former areas of tin extraction in Cornwall [86,129], copper and lead mining in southern Spain [130], and roofing slate exploitation in eastern Czechia [131]. There are also publications, which focus on specific types of stone resources and address various associated issues such as geological context, techniques of extraction, past and present use, as well as potential geoheritage value [103,132–135].

The cultural dimension of mining and quarrying has received an increasing recognition from the World Heritage Committee of UNESCO and currently more than 20 former sites of natural resource exploitation are listed as World Heritage properties in countries such as Great Britain, Germany, Czechia, Sweden, Spain, Poland, and Chile. Among the most recent examples is the Erzgebirge/Krušnohoří Mining Region along the Czech/German border, inscribed in 2019 and consisting of 22 key localities on both sides of the border (Figure 4). Each of these, in turn, encompasses several more sites of interest. The area was a mining region since the 12th to the 20th century and was particularly thriving in the 15th and 16th centuries when most of silver available in Europe came from the Erzgebirge mines.



**Figure 4.** Mining heritage of Erzgebirge/Krušnohoří Mining Region—a transboundary UNESCO World Heritage property in Czechia/Germany. (a) evidence of exploitation of ore-bearing veins near the town of Horní Blatna, Czechia, (b) waste heaps and terrain depressions after collapsed shafts on Mt. Mědník, Czechia, (c) remnants of a large tin mine in Geyer, Germany, (d) preserved traditional buildings of an old mining town, Horní Blatna, Czechia (all photographs by the authors).

With the contemporary increasing interest in geotourism, which includes mining heritage attractions, more and more quarries are being developed for tourists and offer educational opportunities. Reflecting this trend, various recent publications explore possibilities to use mining heritage as a foundation for geotourism development [136–148], although it was also pointed out that tourist visits to mining sites are hundreds of years old [149]. Various means of conveying information are employed at currently accessible sites, from individual information panels through discovery routes within individual quarries to longer trails linking adjacent quarries or mining heritage sites [150]. Conversion of a former underground mine into a tourist site usually requires a lot more effort and observation of the legal framework that controls the maintenance of underground mine spaces. Nonetheless, old mines of coal, gold, silver, ores, salt, flint, and chert, are increasingly popular visitation sites, and guided tours typically combine information about geological foundations, history of discovery, mining operations, and the use of a given resource in the past and at present [151]. Besides geotourism, Prosser [152] has recently shown the potential of quarrying to make connections with the local communities, emphasizing extraction of stone resources since antiquity as part of local history, the use of stone in buildings well-known to the locals, including dwelling houses in which they still live, conversion to local recreation grounds, and various educational initiatives implemented within former quarries.

Exploration of mining heritage extends to include industrial activities, which do not necessarily produce lasting visible evidence and do not create ‘mining landscapes’ but contribute to the cultural history of the region. This is the case of petroleum industry [146,153–155].

## 6. Cultural Heritage Dimension of Natural Geophysical Disasters

Natural processes, particularly catastrophic ones, often interfere with cultural heritage, damaging the latter or destroying it completely (Figure 5). Recent examples of substantial loss of cultural heritage include large-scale destruction of UNESCO World Heritage properties in Kathmandu, Nepal, due to the Gorkha earthquake in April 2015, an earlier damage of another UNESCO site in Bam, Iran, caused by an earthquake in 2003, and the consequences of the 2008 Wenchuan earthquake in Sichuan, China. However, ongoing exogenic processes may also pose a serious threat to sites of cultural significance, as shown by examples of heritage-listed religious sites of Hinduism affected by fluvial erosion and channel shifts of the Brahmaputra river in India [156], recurrent landslides, slow-moving slope deformations and gully erosion affecting historical settlements and structures in Italy [157,158], or historical buildings in the town of Calatayud in Spain, suffering from gypsum dissolution and land subsidence [159]. The ruined medieval church in the village of Trzęsacz in NW Poland, perched atop a coastal cliff (Figure 5a), is another example of a historical site that suffered from geomorphic processes, but one can also argue that its significance actually increased, being now also important for coastal geomorphology as a benchmark of long-term erosion [160]. In a similar way, the significance of the landslide-affected town of Bagnoregio in Italy has risen, especially after the opening of a dedicated landslide museum in 2012 [158]. Less dramatic in the long-term are consequences of river floods, commemorated by flood marks found on buildings located next to river channels (Figure 5b) [161–163].



**Figure 5.** Natural hazards and disasters in the cultural heritage context. (a) remnants of a medieval church in Trzęsacz, northern Poland, destroyed due to sea cliff retreat, (b) flood marks in the town of Eibelsstadt on the River Main, Germany, (c) ruins of Herculaneum, Italy, excavated from beneath lahar and pyroclastic surge deposits from the AD79 eruption of Mt. Vesuvius, (d) ruins of a church in San Juan Parangaricutiro, Mexico, destroyed by a lava flow from the Parícutin volcano in 1944 (all photographs by the authors).

Of special interest are localities where everyday life in ancient times was suddenly interrupted by natural events such as volcanic eruptions, including lava flows or pyroclastic deposits overwhelming buildings, or earthquakes. These sites, if uncovered by archaeologists, become windows to the past of unprecedented importance, but they also show complex relationships between people and nature and can be used for geo-education [164,165]. The ruins of Pompeii and Herculaneum continue to attract interest of scientists exploring the history of their destruction by the 79AD eruption of Mt. Vesuvius (Figure 5c) [166,167]. Likewise, the site of Akrotiri on the island of Santorini has become famous due to its preservation after the catastrophic explosion of Thera volcano around 1600 BC [168]. Perhaps less known are the ruins of the pre-Columbian ceremonial site of Cuicuilco in Mexico City, partly buried by lava flows some  $1670 \pm 35$  years BP, in this case probably long after abandonment by the local population [31]. There are also various examples of ancient structures destroyed by earthquakes, particularly in the Mediterranean world [169–171].

For more recent natural disasters, one can argue that the very fact of partial destruction turned a place, which would be fairly ordinary otherwise, into a site of mixed, natural-cultural importance. This is the case of the former village of San Juan Parangaricutiro in Mexico, overwhelmed in 1944 by a lava flow fed by the Parícutin volcano [172]. The sole vestige of the town is the ruined church, partly filled by lava, with the tower rising above the rugged lava surface (Figure 5d). The church itself was of minor architectural significance, but after the eruption the site has become a tourist attraction, whereas for the local population it is also a pilgrimage site and a sign of supernatural protection of the church. Similarly, towns and villages abandoned following strong earthquakes, recurrent landslides, and flood disasters, turning into ‘ghost towns’ if they were not totally demolished, may also become localities of combined geoheritage and cultural significance as testaments of the power of natural forces [173].

This field of inquiry is also closely related to geo-mythology and other intangible cultural heritage, as will be discussed in Section 10.

## 7. Geoheritage and the History of Science

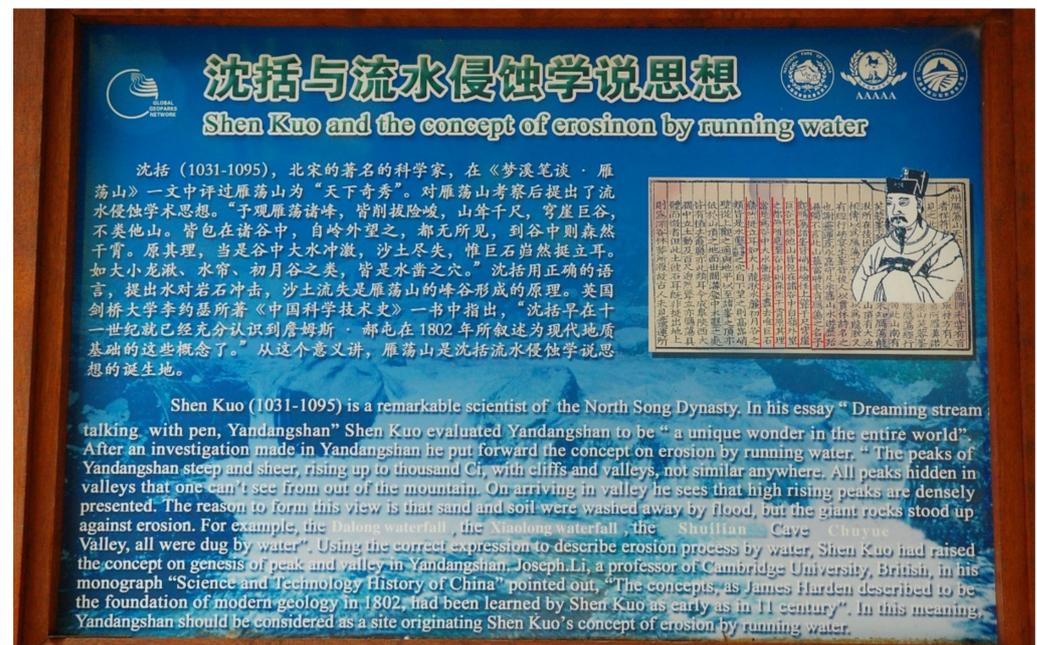
A substantial part of geoheritage is linked with the history of Earth sciences, which is another part of cultural history. Of particular importance are localities where significant observations and discoveries were made, so that these sites have become benchmarks for subsequent studies. These discoveries are in turn connected with the names of people, who were later recognized, as geosciences developed, as the leading representatives of academia, influential researchers, and founders of ‘schools of thought’, which may have lasted for many decades. In these cases, relevant geosites do not only inform about specific rocks, fossils or structures, but also provide opportunities to recall the life and contribution of an eminent scientific figure. In addition, the further back in time we go, the more often authors of these observations were not highly specialized geologists, but rather people of broad interests and multiple skills, including poetry and art, and well-travelled.

These discoveries are usually recalled by erecting simple commemorating plaques or interpretation panels at the sites of concern. The former, however, add a cultural dimension to a geosite (e.g., localities visited by Johann Wolfgang Goethe in the sandstone tablelands of Central Europe [174]), but do not help to better understand the significance of a site. By contrast, the latter inform about the nature of the scientific achievement and sometimes about the persons themselves, as in the case of Hutton’s Section in Edinburgh, Scotland, where James Hutton demonstrated the intrusive origin of a dolerite dyke. In fact, England and Scotland are areas where many important discoveries were made during the early stages of Earth science development, and these are brought back to attention through both more specialist publications aimed at professionals and efforts to explain the sites themselves to the general public [175,176]. The history, scientific content, and educational role of geological collections in museums is another recurrent theme in recent publications, illustrating another dimension of geoheritage and history of science linkages [177–180]. For

example, Hose [177] summarized the main characteristics of leading geological museums in England, France, Italy, and Germany, whereas Vicedo et al. [181] emphasized the value of movable palaeontological heritage collected in the Museum of Natural History in Barcelona.

In the city of Prague, Czechia, an educational trail was set up in the valleys of Dalejské and Prokopské údolí, where numerous limestone quarries expose a marine succession of Ordovician, Silurian, and Devonian age, including some globally recognized stratotypes, most associated with the work of Joachim Barrande in the 19th century. At several stops, panels inform about the significance of these sites for the development of geology, whereas the quarries themselves are well exposed and easily available for viewing. Another recent study from Czechia recalls the contribution of J.W. Goethe to the Plutonism/Neptunism debate at the turn of the 19th century and his efforts to explain the origin of Komorná hůrka cinder cone [182]. The site itself preserves the original adit dug to test the hypothesis of volcanic versus marine origin of basalt, whereas interpretation panels put it into wider regional and scientific context. In the Alps, in turn, especially in Switzerland, numerous geosites are highly valued not only for their intrinsic value, but also for their importance for the advancements in the theory of mountain glaciation and mountain building [183]. The ruins of Serapeo in Pozzuoli, Italy, with perforations imposed by burrowing marine molluscs, played an important role in the understanding of cyclic sea-level changes and were immortalized on the cover of Lyell's 'Principles of Geology', first printed in 1830 [184]. However, not all these important localities have on-site interpretation facilities, and the awareness of their significance is then limited to a rather narrow circle of professionals.

It is worth noting that advances in geosciences and the means to commemorate them are not limited to the Western world. Figure 6 shows a panel from Yandangshan UNESCO Global Geopark in southern China that recalls how a Chinese scholar Shen Kuo, living in the 11th century, explained the role of running water in eroding the rocks and the land.



**Figure 6.** Interpretation panel in Yandangshan UNESCO Global Geopark, China, referring to the history of scientific inquiry in the field of geosciences (photograph by the authors).

## 8. Geoheritage and Early Tourism

Tourism can be defined and analysed from various perspectives, but no one doubts that it is an inseparable part of culture. Whereas the extremely broad subject of contemporary geotourism, addressed in an ever-growing number of publications from all around the world, is beyond the scope of this review as it does not yet qualify as part of "cultural

heritage”, early tourism with its tangible evidence and intangible legacy is certainly of heritage value.

In Europe, linkages between geoheritage and early tourism are best expressed in the context of “Grand Tours” of the 17th to 19th centuries. These travels are understood as long journeys undertaken by representatives of contemporaneous aristocratic elites, especially from western and northern Europe, with the Italian peninsula as the ultimate destination. The purpose was to become acquainted with the rich cultural heritage of Italy, traced back to Greco-Roman times, fulfilled through visits to famous historical cities (Venice, Florence, Rome) and sites of archaeological importance (e.g., Pompeii). However, many Grand Tour practitioners travelling across the Alps and the Italian peninsula did not ignore impressive natural features such as the glaciers and high-mountain scenery of the Alps [171]. In Italy itself, active volcanoes such as Mt. Vesuvius, Mt. Etna and the Aeolian Islands aroused curiosity, and so did related geothermal phenomena such as those at Campi Flegrei near Naples, and the interest can be traced back into antiquity [19]. Sometimes it is not straightforward to draw a clear dividing line between early tourism and the development of science (see Section 7). A recent project aimed to refresh the memory about the long journey of J.W. Goethe across Italy in the late 18th century and to highlight the aptness of his observations about geology and landscapes [185]. Thus, the travelling Goethe was as much a person undertaking the Grand Tour and a geotourist, as he was a naturalist, whose efforts to understand the environment are documented in his travel memoirs.

In a different geographical context, Migoń [174] reviewed the history of tourism in the Sudetes range in Central Europe, noting an interest of 18th century travellers in sandstone rock cities and the evidence of amazement in these unique rock formations recorded in travel diaries. Likewise, the nearby Karkonosze Mountains and their surroundings attracted tourists offering vistas of unusual geomorphic formations such as waterfalls, glacial cirques (not interpreted as such in those times), non-karstic fissure caves, and granite tors [101,174]. In the 19th century, the Sudetes, like many other mountains and uplands in the contemporaneous German lands, were renowned for their sites of geological and geomorphological interest. In Britain, the Romantic period between the late 18th and mid-19th centuries saw a surge of interest in natural landscapes too, as extensively documented for the wild Lake District in northern England [186] and other parts of England [187]. Gordon and Baker [188], in turn, drew attention to the “tourism of awe” that typified the 18th and 19th century visits to the Scottish Highlands, emphasizing ubiquitous appreciation of wild Highland scenery, with waterfalls, glacial troughs, and outcrops of columnar jointing in basalts. A related theme is early geotourism provisions, such as purposefully designed guidebooks [189] and outdoor geological models [174].

## 9. Geoheritage, Art and Literature

Linkages between geoheritage and art are not among the most popular topics and were explored in a rather limited number of publications, even though opportunities of thematic studies are multiple [190,191], but this may change, following the recent plea of Motte and McInnes [192] that “it is stimulating to continue the adventure of bridging sciences and art”. Nevertheless, various studies have been recently published, addressing subjects such as natural landscape features as a source of inspiration for artists, or the use of old paintings to inform attempts to decipher landform change in the past few centuries. In this context, art presentations of sites that were subsequently destroyed, either by natural forces or due to human activities, are of particular importance. A relevant example is the site of the White and Pink Terraces in the North Island of New Zealand, once acclaimed a ‘wonder of the world’, but irreversibly annihilated through the explosion of the Tarawera volcano in 1886 [193]. In the Alps, the pre-20th century artistic imagery is now a most useful source of information about past extents of glaciers, used in conjunction with other lines of evidence [194]. In a similar vein, analysis of old paintings, postcards, and engravings of the coastal scenery in Brittany, France, helped understanding the patterns of coastal change and may inform current coastal management [192]. Pullin [195] offered an insightful

analysis of the life and work of Eugene von Guérard, a 19th century landscape painter of German origin, who began his career in Germany, but spent many years in Australia and New Zealand, portraying various volcanic features with a very high degree of accuracy. The common use of sites of geological or geomorphological significance as motifs for landscape paintings was also emphasized for the Scottish Highlands [188], the Isle of Wight in southern England [196], the chalk cliffs of the island of Rügen in Germany [191], and badland landscapes of Italy [197]. Landscape paintings from the period of the Renaissance (15th–16th century) were analysed by Nesci and Borchia [198], who aimed to see if the landscape backdrops were imaginary or real sceneries, confirming the latter. Further examples and relevant references were provided in a brief, but informative overview of the subject by Gordon [190].

Art other than painting is rarely presented in the context of geoheritage. One novel aspect is exploration of the content of municipal heraldry in Portugal, with the emphasis on geological and geomorphological elements demonstrating close links with the landscape and the sense of place underpinned by physical features [199]. The appearance of landscapes of geoheritage value in movies and related opportunities for geotourism has also been recently addressed [200].

Natural landscapes and individual curious landforms have often been inspirational to poets and writers, especially in the Romantic period of the 19th century, so that one can find various direct and indirect references to diverse geological and geomorphological phenomena [190,191]. Examples of this kind demonstrate the cultural value of geoheritage and add value to localities otherwise important for scientific reasons.

## 10. Geoheritage and Intangible Cultural Heritage

The last two decades have seen an increasing awareness of the contribution that intangible cultural heritage offers to better appreciate and understand geoheritage. As for the other themes, this one too appears in various forms such as preservation of memory of natural geophysical disasters and their consequences, explanation of natural processes by indigenous communities unfamiliar with the scientific foundation of geoheritage, traditions related to various aspects of natural heritage, and reconstructed geo-mythology.

Geo-mythology issues were reviewed and illustrated by diverse examples from around the world in an edited work [201], which highlighted its importance for geological sciences. Various authors demonstrated that mythical events embedded in the collective memory of indigenous communities and related place names may in fact inform about catastrophic geophysical events such as earthquakes [202–204], tsunamis [205,206], or dramatic environmental changes due to climate change and ice expansion [207]. The most recent additions to the subject are the scholarly monograph by Burbery [208] and a review of folk tales related to submerged lands due to sudden or gradual geophysical change by Nunn [209]. However, possible linkages between the content of tales and real geological events have to be explored with extreme care due to possibilities of various recent ‘contaminations’, as demonstrated by referencing to Aboriginal stories about ‘falls from the sky’, which could be interpreted as eye-witnessed meteorite impacts but were in fact inconsistent with the timing of the origin of craters [210]. The iconic Mount Olympus in Greece was also presented in the context of ancient mythology versus modern geology [211], whereas Khoshraftar and Farsani [212] argued that geo-mythological associations at cultural heritage sites may increase interest among visitors, which in turn can be used to offer more comprehensive interpretation of geosites.

In other cases, folk tales and associated traditions and rituals are not related to real events from the geological past but simply reflect beliefs of the local population passed on from the era prior to scientific discoveries in the field of geosciences. Exploration of such traditions in the geoheritage context seems to be an emerging theme, as demonstrated by recent contributions from the Bohemian Massif in Czechia [213], the Ardennes in Belgium [214] and Lithuania [17]. Geomorphological features subject to folk explanation

include distinctively shaped rock outcrops, erratic boulders, dead-ice kettles, meander loops, and caves.

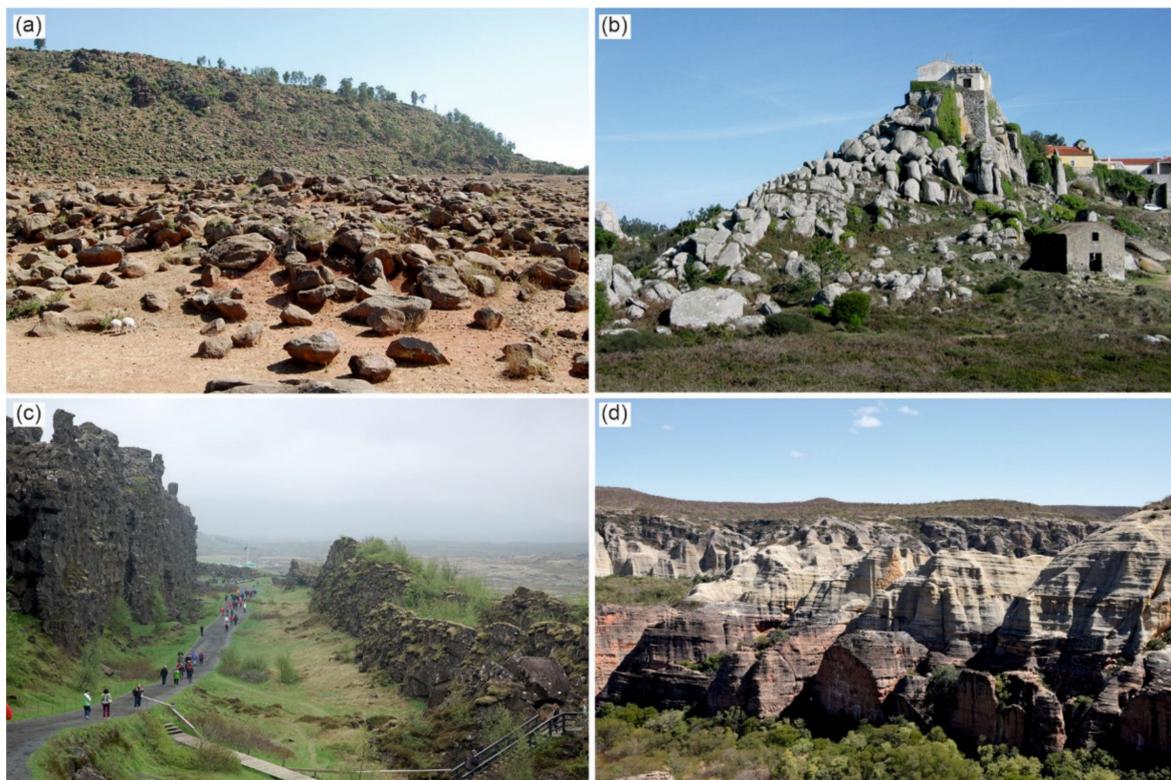
Apart from oral traditions passed on from one generation to another, geoheritage connections may be also found in traditional tattooing, specific phrases used in local languages, and cultural activities [215].

### 11. Geoheritage—Added Value at Cultural Heritage Sites

In Sections 2 and 4, we presented geoheritage sites, which show an additional value associated with cultural heritage. However, the relationship can be also in reverse, in that cultural values are considered as superior, but this should not lead to the neglect of geodiversity and geoheritage aspects at these sites. This issue can be demonstrated at many UNESCO World Heritage sites, which were inscribed solely in the recognition of their cultural value but may contain interesting landforms and rock outcrops [216]. Selected recent examples of this kind, other than those referred to above, include:

- The artificial caves of Elephanta off the Bombay coast in India, with numerous paintings and sculptures, excavated in multi-layered basaltic lava flows. A recent publication [217] drew attention to the paucity of geological information about the site and aimed to redress the balance.
- The archaeological area of Aksum in Ethiopia, known for the famous stelae, subterranean necropolises and ruined buildings. These historical monuments are integrated with the erosional scenery of exposed syenite plugs, with impressive rock cliffs, talus-covered slopes and boulder blankets (Figure 7a) [218].
- The rock island of Mont-Saint-Michel in Normandy, France [219], made famous by the Benedictine Abbey erected on the top, but being also a first-class example of rock-controlled relief amidst megatidal flats.
- The Cultural Landscape of Sintra in Portugal, where various elements of the 19th century Romantic architecture, including gardens and parks, are incorporated into granite scenery with impressive crags and boulder fields (Figure 7b), giving way to sea cliffs and shore platforms [220].
- The archaeological site of Petra in Jordan, with numerous elaborate structures dated to the turn of BC/AD times, half-built and half-carved into striking red sandstone outcrops. Geomorphology provides a magnificent setting to the ancient city, with high cliffs, rock platforms, extremely narrow gorges, and a variety of selective weathering features [221].
- The Thingvellir area in Iceland, inscribed in recognition of its cultural significance for the history of parliamentary culture, but at the same time being “perhaps the best place on this planet to understand the process of rupturing of the crust in response to the pulling forces of plate movements” [222]. The site contains superb examples of open fractures, trenches and grabens, waterfalls and lava outcrops (Figure 7c).

It is also appropriate to mention rock art sites, which often sit amidst spectacular scenery, but the focus of research tends to be on the content and interpretation of paintings and engravings. Again, the UNESCO World Heritage list provides examples (e.g., Tadrart Acacus, Libya; Serra da Capivara, Brazil—Figure 7d) and there are many less known sites on all continents. Nonetheless, a few recent publications analysed the wider geological and geomorphological context of such localities [223,224] and consideration of environmental history may significantly help in interpretation of rock art and explanation of its current state [225]. Similarly, caves renowned for rock art or other archaeological discoveries are examples of mixed cultural-natural heritage and hence, geomorphosites, even though their core values are associated with the importance for the history of mankind [7,226,227].



**Figure 7.** Geoheritage context of selected UNESCO World Heritage cultural properties. (a) the archaeological area of Aksum, Ethiopia, with flat-topped syenite plugs, pediments and intriguing boulder fields, (b) granite residual hills and boulders in the cultural landscape of Sintra, Portugal, (c) graben in the lava plateau at Thingvellir, Iceland, testifies to recent crustal extension at the plate boundary, (d) magnificent sandstone and conglomerate cliffs provide the geomorphic context for the rock art site of Serra da Capivara, Brazil (all photographs by the authors).

## 12. Systematic Approach versus Multiple Linkages

The review above shows that the interface of geoheritage and cultural heritage is very broad, and many specific themes are explored, even though some appear more often addressed than others. In addition, in tracing recent literature one can easily observe that the range of such themes increases, and this trend is likely to continue in response to the expansion of the UNESCO Global Geopark Network, which emphasizes geoheritage—cultural heritage linkages, new international initiatives such as World Geodiversity Day, and a growing awareness among scientists that inter- and transdisciplinary studies have considerable merit. Therefore, it is tempting to offer a provisional systematic classification that would facilitate navigation across this increasingly complex field of inquiry. This, however, seems a challenging task as approaches to classification can be different, being not mutually exclusive (Table 1).

Perhaps the most obvious classification for geoscientists would be one that makes the type of geoheritage central, paying less attention to the kind of relationships with cultural heritage (Table 1, column A). This stance reflects the internal division of Earth sciences and defines the possible contribution that petrologists, palaeontologists, structural geologists and volcanologists, geomorphologists or hydrologists can have. However, some sub-disciplines may fit into several categories, especially volcanology, whose linkages with cultural heritage are often explored. Cultural dimension may be shown by specific types of volcanic rocks used for various purposes, volcanoes as singular landforms, volcanic landscapes, geothermal phenomena, as well as information about past eruptions. In this approach, the classification system may be easily expanded by adding sub-categories, for

example defining types of landforms more specifically (fluvial, mass movement-related, volcanic, karst).

**Table 1.** Various approaches (A–G) with their underlying factors important to classification of themes at the geoheritage—cultural heritage interface.

A	B	C	D	E	F	G
Type of geoheritage	Type of human activity	Spatial scale	Temporal scale	Nature of evidence	Core values	Principal context
Rocks/stones/minerals Fossils Geological structures Landforms Landscapes Springs and other hydrological phenomena Soils	Building construction Farming Mining, quarrying and industrial architecture Tourism and travel Science and education Art Craft	Cultural landscape Urban (town, city) Rural (village) Individual site/object Subterranean sites	Prehistory Antiquity Medieval Modern era	Tangible • in situ • ex situ Intangible • language • traditions, • customs • myths and beliefs • history	Geoheritage as core value Geoheritage as additional value Equal standing	Geo-conservation Geotourism Geo-education Raising awareness

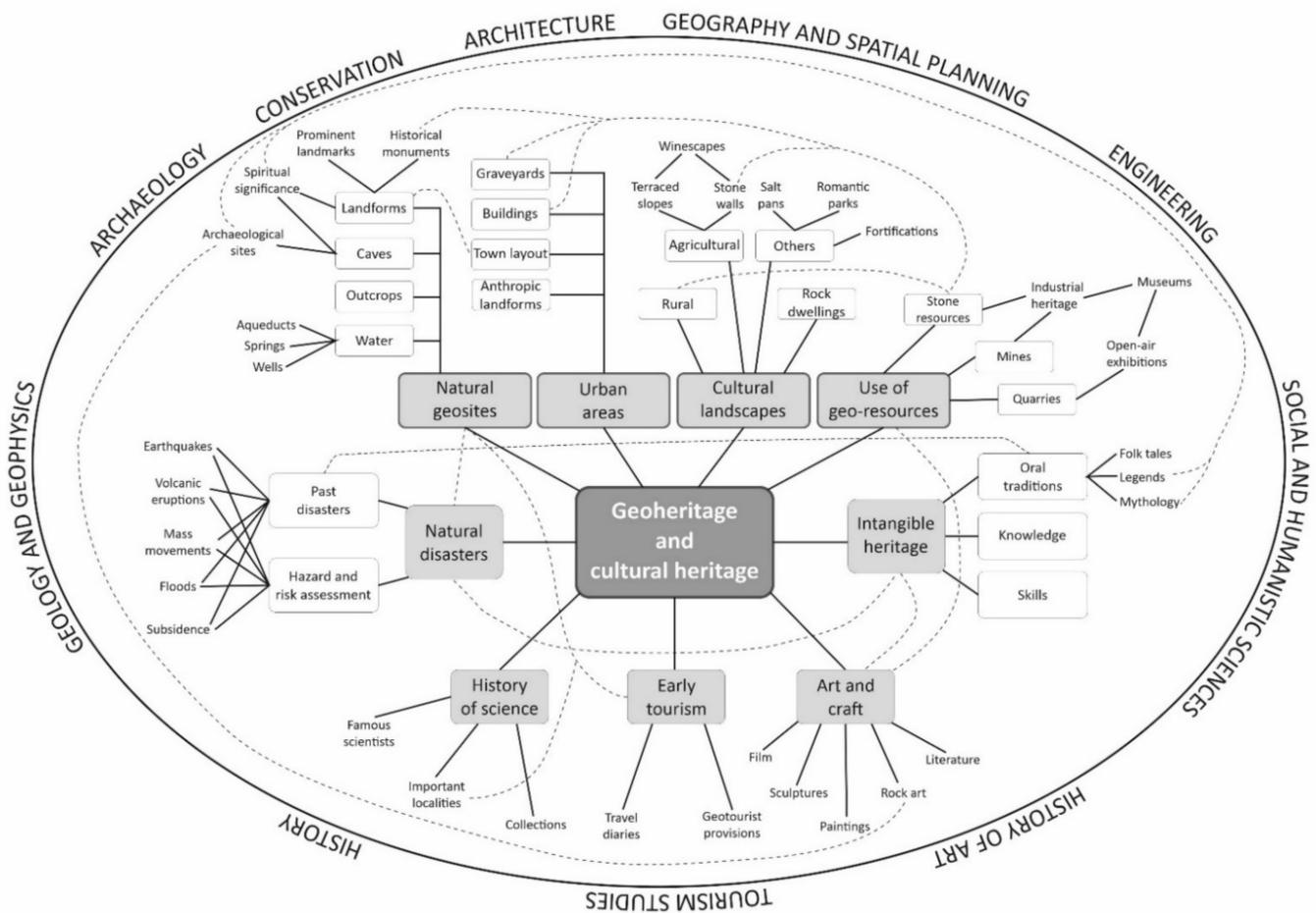
An opposite way involves the type of human activity as the basis of a classification system (Table 1, column B), as in each case the nature of relationships with geoheritage is different and includes exploitation and re-use (e.g., mineral resources and building stones), adaptation to natural conditions (town planning, farming in difficult terrains), adjustment to societal needs (adaptation of caves for visitors), or recording and interpretation (education, art).

The next two approaches emphasize the spatial and temporal scale, respectively. Considering space (Table 1, column C), one can categorize inquiries according to the size of an area at which the relationships are examined. The broadest scale is represented by cultural landscapes, where protracted human use of natural resources resulted in the origin of a distinctive scenery, whose appearance, both at large and in detail, is underpinned by geology and geomorphology. Terraced wine-growing landscapes and mining districts are relevant examples. Urban geoheritage follows, usually encompassing large areas, with several specific themes that are addressed. The main ones are adjustment of urban design to natural landforms and the use of several characteristic building stones across a city. However, large cities may be also considered as cultural landscapes, as exemplified by the UNESCO World Heritage-listed Rio de Janeiro. Rural heritage comes next, although again these small inhabited spatial units may be part of much wider cultural landscapes. Defining the boundaries between these categories in numerical terms seems thus neither possible nor helpful. The decreasing spatial scale is completed with individual objects (if the focus is on anthropic constructs such as buildings), or sites (landforms, rock outcrops). A category of its own is made by subterranean sites, not visible from the ground and not fitting any of the above categories. In fact, the size of subterranean sites may vary broadly, from small caves and single adits to extensive underground systems of quarries, mines and dwelling spaces. Classification in respect to timeline is another possibility, allowing for easier identification of potential partners in scientific endeavour (archaeologists, historians, art historians), but is unlikely to be universal. The proposal shown in Table 1 (column D) is obviously Mediterranean/Europocentric and reflects major phases of civilization development and historical breakthroughs experienced in this part of the world, but it will not be applicable to other continents. For instance, it will have little relevance to East Asia, nor to Australia and Oceania.

The mutual relationships between geo- and cultural heritage may also be examined from the perspective of tangibility/intangibility of evidence (Table 1, column E). The former is more explored and can be further divided into inquiries focused on in situ objects of interest (landforms, sites of exploitation of natural resources, hydrological phenomena etc.) and those, where objects of value are preserved ex situ (e.g., mineral and fossil collections). The latter, increasingly appreciated in the last few decades, may also warrant further subdivision depending on their type (language, mythology, customs etc.).

The review of publications has also shown that the position of geoheritage values in respect to cultural heritage varies (Table 1, column F). In some studies, geoheritage and geodiversity are central, whereas cultural associations are considered as added values that enhance the significance of a site. This approach is particularly common in valorization of geosites in the context of tourist use, underlined by an assumption that the diversity of values makes the site more attractive and allows for implementation of various innovative tools and concepts in geo-education. In other cases, however, a given site is primarily known for its cultural heritage values and the efforts of geoscientists are directed to show its less known face and perhaps to achieve some sort of balance in perception of significance, in response to the general limited awareness of geoheritage and geodiversity. Equal standing is another option, as demonstrated by UNESCO World Heritage mixed properties, where neither cultural nor natural values are superior in respect to one another. Finally, the main purpose and context of studies is emphasized, acknowledging that they often have a clearly defined end-user (Table 1, column G). Thus, some have a distinct geoconservation slant, aiming to deliver practical solutions how to save geological, geomorphological, mining or building stone heritage that may face various threats arising from ongoing development and deteriorating state of environment. Many publications explore the linkages in the context of geotourism and its possible enhancement, particularly with reference to geoparks and towns/cities, whereas others focus on opportunities to use these cross-disciplinary relationships in formal and informal education, both in- and outdoor. There are also studies, which are not addressed to the specific users at the time they are presented, but simply contribute to the enlargement of our knowledge and understanding of the environment and history.

One may thus ask if classifications in this particular context are useful at all. One observation clearly emerging from the literature review is that various themes and fields of inquiry are overlapping and interlinked. For example, the frequently addressed issues of mining and quarrying heritage, distinguished as a separate theme in this paper (Section 5), are closely connected with cultural landscapes and urban geoheritage due to use of quarried stone, overlap with the history of science, and may have links with early tourism (visitations of famous ancient quarries, such as in Carrara, Italy) and art, being recorded on paintings. Mining culture may also influence intangible local and regional heritage. Likewise, rock art is relevant to the geomorphological heritage, as rock art sites are usually associated with distinctive landforms, and history of geoscience, giving insights into past environmental changes. Geomythology and other expressions of intangible cultural heritage are linked with past geophysical disasters and may help to better understand the latter. For all these reasons, we also present an alternative way to show the wide thematic spectrum within the broadly defined geoheritage—cultural heritage interface, using a mind map (Figure 8). It shows the main and the less explored themes identified in this paper, also indicating some specific areas of interest, as well as including the most evident linkages between them. However, it should not be considered as an exhaustive, definitive proposal and more themes and connections can be added, reflecting the variety of subjects, approaches, and cultural contexts.



**Figure 8.** Themes explored at the geoheritage—cultural heritage interface, divided into main (framed by thicker lines) and secondary ones, and the most evident connections between specific subjects (dashed lines). The outer ellipse shows sciences whose fields of interest overlap with geoheritage studies.

### 13. Conclusions

Two main conclusions emerging from this review are: (1) the cultural relevance of geoheritage is widely recognized and has become a very popular subject of studies, which explore various aspects of this interface, resulting in a broad range of themes and specific topics; (2) among these different themes some generate much more attention than others, resulting in general thematic imbalance. Among the most frequently addressed subjects are geoheritage in urban space, with particular focus on heritage stones and their use in historical building construction as well as on recognition of geosites and their accessibility, and mining/quarrying heritage, along with associated industrial architecture. The reasons are likely complex but may include both the urgent need for such studies, driven by conservation priorities, as well as the response to plans to increase or diversify tourist visitation. In each case, preferential funding may be available. Urban space is also an obvious place to explore for scientists based in respective cities. Apparently much less explored, at least by people with a geoscience background who publish in geoscience journals, are themes more linked with history such as history of scientific discoveries, of early tourism, and the whole sphere of art. The latter may seem a subject without significant implications for geosciences themselves, but this is not true. Old landscape paintings were shown to be valuable sources of information about landform change during historical times and may inform environmental management strategies. The literature survey also revealed a very uneven regional coverage. The vast majority of studies focused on relationships between geoheritage and cultural heritage came from Europe and the subject seems to grow in popularity in South America (specifically Brazil), whereas the

heritage of Asian and African countries, as well as of Australia and Oceania, appears much less explored in this context, at least within leading international journals focused on geoheritage and geoconservation.

Recent years have seen an intensification of outreach activities among geoscience practitioners, arising from a growing realization that geoheritage and geodiversity do not enjoy sufficient recognition in society and their importance is often ignored [228,229]. Within this unfortunate situation, there is poor understanding of the crucial underpinning of many cultural values, both tangible and intangible, by geoheritage and geodiversity elements. Notably, whereas procedures of geosite assessment for education and geotourism purposes often include cultural elements as an added value, elevating the significance of a site and making it more appealing to the general public [230–233], cultural heritage is often assessed without due attention paid to its landscape context. One type of evidence supporting this statement is the inscription of many UNESCO World Heritage cultural properties, which undoubtedly owe their unique characteristics to the natural setting (e.g., rock art sites, sacred mountains, mining heritage), but the setting itself is rarely highlighted. Consequences of this bias are a lack of awareness of geoheritage values among visitors, even at sites with spectacular geoheritage, as recently demonstrated via a visitors' survey at Meteora in Greece [234], or in the sandstone rock cities in the Bohemian Paradise UNESCO Global Geopark [235]. Therefore, a key research priority is action to foster understanding of geoheritage as a foundation value for cultural heritage, which can be achieved by publications exploring geoheritage and geodiversity of sites and areas recognized mainly for their cultural values. Parallel to that could be practical involvement in communication and promotion of geoheritage at cultural heritage sites to achieve more integrated interpretation offered to visitors. On the other hand, links with cultural heritage are worth underlining at primarily geoheritage sites too, as they may relate more immediately to popular experience and interests. Likewise, studies of under-researched themes, such as geoheritage in art and geoheritage, and geodiversity-related intangible cultural heritage also emerge as priorities.

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