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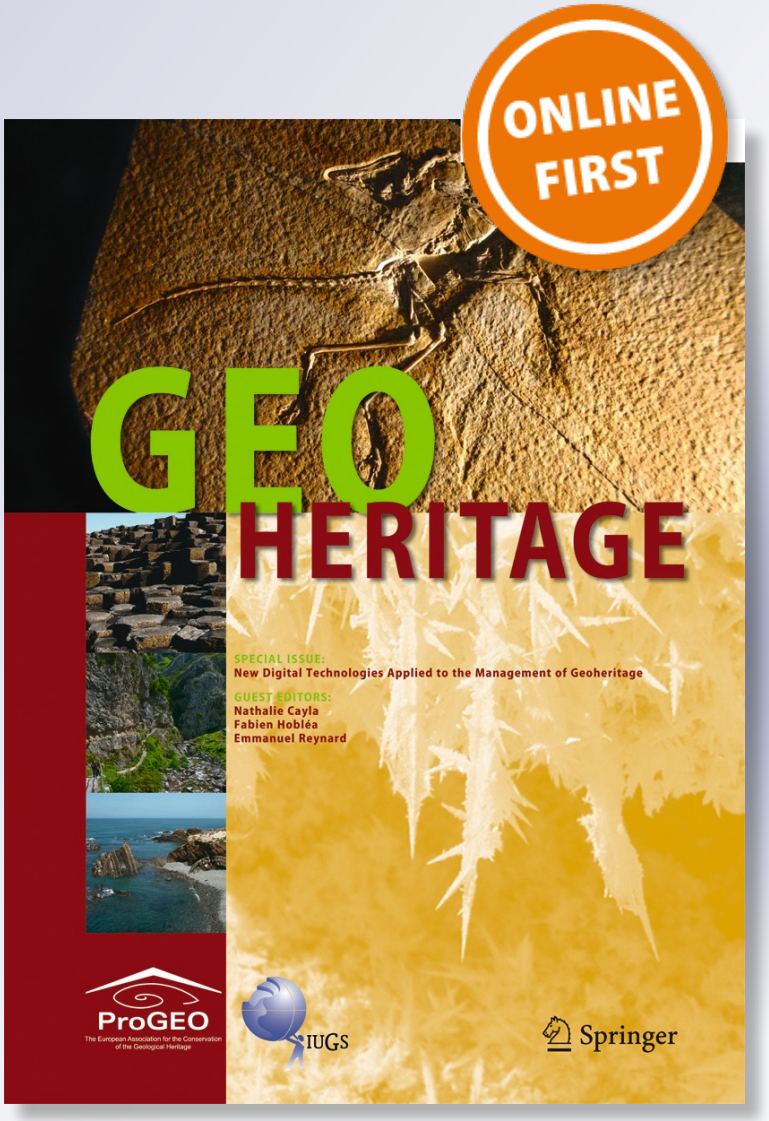

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ORIGINAL ARTICLE

Characterization and Valuation of Paleontological Heritage: A Perspective from Argentina

María Luz Endere · José Luis Prado

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Abstract Argentina has a rich and diverse paleontological heritage, with fossil sites pertaining to every epoch from the Cambrian to the Holocene. In recent years, National Law 25.743/2003 has been more useful to achieve a basic level of planning protection for many of Argentina's important fossil sites. In this article, a methodology is proposed for assessing the heritage values of paleontological sites in order to justify their inclusion into national and regional territory planning, an outstanding guarantee protection from the adverse effects of developments. Building knowledge and understanding of the landscapes and their resources, and developing assessment criteria are essential to influencing land planning policy, as well as increasing public awareness and appreciation of paleontological heritage.

Keywords Heritage value · Paleontology · Fossil sites · Land planning

Introduction

Paleontological heritage is not easy to define due to its complex nature and the number of issues related to its legal protection and scientific interest. Both fossil sites and collections made from them form our paleontological heritage and include a large variety of items including the remains, imprints, and traces of once living organisms still preserved on the Earth (on surface or in stratigraphy) or immersed in water. They may be bones and teeth, shells, leaf impressions, footprints, or burrows. The statement that fossils are nonrenewable scientific resources is the main justification for their protection and the reason for being considered part of our shared "heritage" with the exception of those that make up mineral energy such as coal. It is generally accepted that fossils are not only rare but also useful, and even when invertebrate and plant fossils are more abundant than vertebrate fossils, some of them are exceptional because of their preservation. Most vertebrate fossils are considered rare because relatively few sites contain large accumulations of them. The fossil record is the only evidence that life on Earth has existed for more than 3.6 billion years.

The paleontological heritage of Argentina is one of the richest and most diverse in South America and the best documented. The fossil record covers everything from plants and wood (Artabe et al. 2007; Barreda et al. 2007; Pujana et al. 2011) to invertebrate (Del Río et al. 2007) and vertebrate fossils (Cione et al. 2007; Pascual 1961; Vucetich et al. 2007) as well as trace fossils (Aramayo and Manera 1996). Paleontology has a long tradition in Argentina and played an important role in the beginning of paleontology as modern science (Simpson 1980). The first scientific studies began with the contributions of Alcide D' Orbigny (1847) and Charles Darwin (1845) and later continued with the studies of the Argentine naturalist Florentino Ameghino (Gervais and Ameghino 1880). It is also worth mentioning the discovery of the *Megatherium* (Fig. 1) by the Dominican priest Manuel de Torres in 1787, as well as the finding of mastodon remains by former Captain Stephen Alvarez del Fierro in 1766 (Tonni and Pasquali 1999). The record is famous for Caenozoic mammals, mainly from the Pampas and Patagonia (Pascual et al. 1996). In central Patagonia, one of the most important sites is the Gran Barranca of Colhue-Huapi lake (Fig. 2), where the most complete sequence of middle Cenozoic mammals of South America is exposed (Madden et al. 2010). On the Pampas, the sea cliff between the city of Mar del Plata and Pehuen-có, preserves one of the best Plio-Pleistocene mammal sequences known (Pascual et al. 1996). Among the reptile records, the importance of dinosaur sites—mainly those in Patagonia and in

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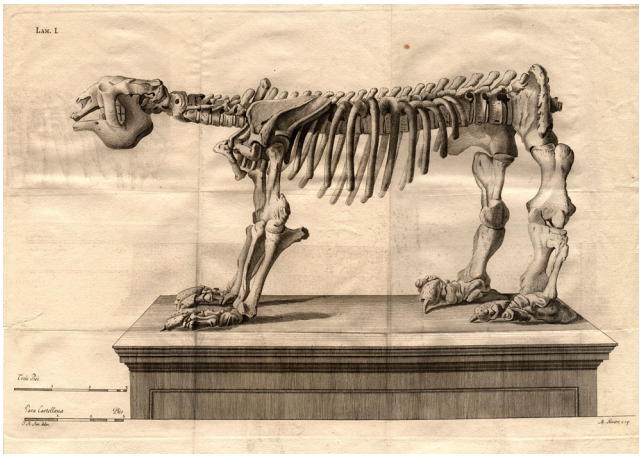

Fig. 1 *Megatherium americanum* Cuvier (1796) mounted on the Royal Cabinet of Natural History in Madrid. Drawing by Juan Bautista Bru de Ramon in 1793

different areas of the Central Andes—must also be emphasized (De la Fuente et al. 2007). For instance, the major record of Triassic tetrapods of the Southern Hemisphere is found in the provinces of San Juan and La Rioja in Argentina (Abdala and Ribeiro 2010; Romer 1960) and is the only paleontological site in Argentina included in the World Heritage List by UNESCO. This site includes two natural parks: Ischigualasto and Talampaya (Fig. 3). Both are rich in their diversity of both plant and vertebrate fossils. Although divided between two Argentinian provinces, the two parks are contiguous and preserve the same geological formation, which has some of the oldest known dinosaur remains making it one of the most important paleontological sites in the world.

Other important fossils from Argentina come from the Antarctic Peninsula where on Vega Island staff from the Museum of La Plata have found bones of a new dinosaur, along with remains of Antarctica's most ancient bird and an array of giant marine reptiles (Coria et al. 2013; Reguero et al. 2013).

Fossil resources from Argentina have been impacted by illicit trafficking. Not surprisingly, the UNESCO Convention on the Means of Prohibiting and Preventing the Illicit Import, Export and Transfer of Ownership of Cultural Property (Warring 2005) and the UNIDROIT Convention on Stolen or Illegally Exported Cultural Objects (Sidorsky 1996) considered "cultural property" as including those objects, which are "of importance for archaeology, prehistory, history, literature, art, or science." Among the categories of objects listed are the "rare collections and specimens of fauna, flora, minerals, and anatomy and objects of paleontological interest."

Another key issue is heritage legislation, because it treats paleontological items as if they were archaeological. In this sense, it is often criticized that paleontological resources are subordinated to those of archaeology and that paleontological excavations are considered archaeological in nature (Alcalá and Morales 1994). Argentinean heritage legislation not only jointly regulates archaeological and paleontological heritage (Law 25.743/2003) but also considers them as part of the public domain of the state (Civil Code (1968), Article 2339 inc. 9 and Article 2340). This means that any fossil of scientific interest is eligible for protection. In practice, all fossils are considered public property because even when some of them might be considered irrelevant—according to current scientific perspective—they may become significant in the future. In summary, paleontological sites and collections have a double dimension because they have characteristics of both natural and cultural heritage. They are also distinguished by their uniqueness, scope, and diversity. However, even when it is clear that fossils are nonrenewable resources and law equally protects all of them, it is worth asking if it is possible or even practical to protect all potential sites. In this sense, it is necessary to discuss the possibility of recognizing different categories of paleontological protection for proper conservation and management in a cost-effective way.

Fig. 2 Gran Barranca of Colhue-Huapi Lake in Patagonia exposes the most complete sequence of middle Cenozoic paleofaunas in South America. It is the only continuous continental fossil record of the Southern Hemisphere between 42 and 18 million years ago

Fig. 3 *View* of the Ischigualasto and Talampaya National Park. It was designated a provincial reserve in 1975, a national park in 1997, and a UNESCO world heritage site in 2000

The incorporation of paleontological heritage in land planning and development policies is not a simple task. It is necessary to precisely define criteria that address the diverse types and characteristics of fossils in each particular region. The aim of this paper is to analyze different categories used to protect paleontological heritage at the international level to further discuss its implementation in Argentina, considering the legal framework and the characteristics of its fossils. As a result, a methodological proposal is presented in order to assess paleontological heritage sites based on a selection of evaluation.

Landscape Approach

In the last decades, a growing trend has become apparent of adopting a more holistic and wider spatial approach of heritage conservation at the international level (Ellis 2008; Hayward 2009). This means not only to select sites for areas as units of protection but also to consider the landscape as a whole, avoiding blank zones.

It is important to point out that this "landscape approach" can be applied to areas of outstanding value—such as those protected under the 1972 UNESCO Convention—as well as to landscapes of national, regional, or local importance. In this sense, this approach differs from the UNESCO's Geopark Program, which aims to recognize remarkable sites that are of interest to earth science (Wimbledon et al. 2000) or the new initiative, PaleoPark (Lipps 2009). It also differs from national parks and natural reserves because it does not change land ownership nor prohibit economic exploitation. On the contrary, it aims to integrate landscape protection into its regional and town planning policies and into its cultural, environmental, agricultural, social, and economic policies in order to guarantee sustainable land use and development, while at the same time preserving the paleontological resources.

The first step in the process leading to landscape protection consists in compiling a detailed knowledge of the landscapes. At least three actions are required: identification, description, and assessment. These actions are essential in order to establish and implement adequate landscape policies aimed at landscape protection, management, and planning through the adoption of specific measures. The need to take into account the particular values assigned to landscapes by the interested parties and the populations concerned has also been emphasized (European Landscape Convention 2000, Article 5; Committee of Ministers 2008).

Furthermore, the development of a landscape-scale approach follows naturally from the adoption of the "ecosystem" approach to conservation (Hayward 2009). The ecosystem approach provides a strategy for the integrated management of land, water, and living resources that promotes conservation and sustainable use in an equitable way. Thus, increasing our understanding of landscapes will help to ensure that future land use is sustainable. In 1995, the Conference of the Parties of the Convention on Biological Diversity adopted the ecosystem approach as the primary framework for action under the convention since it helped to reach a balance of the objectives of the convention (COP2 1995).

Paleontological Heritage Work in Argentina

In Argentina, the site-based conservation approach has traditionally been adopted by legislation. Precisely, under National Law 25.743 and the Civil Code (Article 2339 and 2340), the federal government conferred legal protection to paleontological sites of scientific interest. Fossil sites may also be protected in national parks and natural reserves under the jurisdiction of the National Park Administration created by Law 22.351/1980 (Fig. 4). However, there is a significant

Fig. 4 Petrified Forest National Park in Patagonia

"undiscovered" portion of the paleontological resources in Argentina, which are not adequately protected. In this sense, whole-landscape considerations would also be useful to build upon the network of known paleontological sites and natural reserves already established and will provide a wider, holistic approach to heritage protection. This would also promote the recognition of new sites, not yet identified or that may be discovered by future researchers.

Criteria for Evaluating Paleontological Heritage

Frequently, paleontological heritage evaluations take into account the diverse properties recognized by paleontologists. But other factors, such as those related to the social role attributed to fossil sites by local communities, should also be considered. The integration of different points of view can contribute to qualify heritage sites and fossils within a sociocultural perspective. As a result of all these considerations, the following basic principles for assessing paleontological values are proposed: (a) Fossils are a part of Argentina's heritage by law, (b) most vertebrate fossils are rare, (c) some invertebrate and plant fossils are rare, (d) effective stewardship requires accurate information, (e) fossil collections should be preserved and be available for research and public education, and (f) fossil heritage management should emphasize opportunities for public involvement.

Several criteria concerning the evaluation of the paleontological heritage have already been proposed, related to different values such as intrinsic, cultural and aesthetic, economic, research, educational, and functional (Alcalá and Morales 1994; Hayward 2009; Morales 1996; Morales et al. 1999). In this article, we discuss six groups of criteria: (1) paleontological, (2) geological, (3) contextual, (4) integrity, (5) sociocultural, and (6) socioeconomical criteria. Each value was coded as multistate, where a zero value represents absent or low value, and the subsequent numbers indicate the increasing heritage value. Within the six primary criteria are secondary criteria. The total 23 criteria included in these groups are then used to score the values (Tables 1, 2, 3, 4, 5, and 6) of each identified site. The scores for all site criteria are summed. At least 25 points must be attained in order to

Table 1 Paleontological criteria

Criterion	Grades	Points
Nature of fossil		
	Fossils of scarce scientific significance	1
	Fossils of scientific significance	2
	Fossils of high scientific significance	3
Preservation		
	Poor preservation or fragmental fossils	0
	Good preservation, complete fossils	1
	Exceptional preservation, articulate specimens	2
Diversity of fossils		
	Low	0
	Medium	1
	High	2
Type localities		
	None	0
	One species	1
	Two or more species	2
Taphonomic information		
	Common stratified localities	0
	Localities with high taphonomic value	1
	Localities with exceptional taphonomic value	2

Table 2 Geological criteria

Criterion	Grades	Points
Geological significance		
	Local significance	1
	National significance	2
	International significance	3
Geological integrity of the site		
	Extensive sites	0
	Finite sites	1
	Integrity sites	2
Scientific potential		
	Poor	0
	Fair	1
	Good	2
	Excellent	3

consider the site as having sufficient value for scheduling in the proposed scheme.

Nature of Fossils Sites in which fossil of exceptional scientific importance has been found should receive special consideration.

Preservation The state of preservation of fossils is an important factor when studying the anatomical characteristics of organisms. Sites with well-preserved faunas or floras are therefore more important than those with poorly preserved fossils. This includes sites that preserved rare soft parts.

Table 3 Contextual criteria

Criterion	Grades	Points
Context		
	Low: groups which consist of the partial remnants of an associated set of features or groups which have little scientific or public value	0
	Moderate: groups with partly intact and associated set of features; or groups with moderate scientific or public value	1
	High: groups characterized by a large intact and associated set of features or groups which have an exceptional scientific or public value	2
Visual contribution to landscape		
	Low: barely visible on the ground	1
	Medium: only visible at relatively close proximity	2
	High: clearly visible from some distance	3
	Iconic: stands out monumentally in the landscape	4
Association with archaeological remains		
	No other associated heritage	0
	Associated with an archaeological site	1
	Associated with more than one archaeological site and forms a particularly unique set	2

Table 4 Integrity criteria

Criterion	Grades	Points
Geographic situation		
	Too small or located in a locked core that prevents the development of infrastructure for use	0
	Moderate extent and/or ability to enable complementary infrastructures	1
	Wide spread, also ability to enable complementary infrastructure development and domestic routes	2
Vulnerability to damage related to fossil collecting		
	Somewhat vulnerable to fossil collecting	0
	Very vulnerable to fossil collecting	1

Diversity of Fossils Sites where a great diversity of fossilized organisms has been found (i.e., cooccurrence of vertebrates, invertebrates, and plants), or in which there is a great diversity

Table 5 Sociocultural criteria

Criterion	Grades	Points
Historic value		
	None	0
	Locally significant	1
	Regionally significant	2
	Nationally significant	3
	Internationally significant	4
Educational and interpretation value		
	Poor: features mainly obscured and totally inaccessible	0
	Fair: some features are visible but difficult to access	1
	Moderate: very visible features, good access, nearby educational, or tourist facilities	2
	Excellent: high visibility, intact, nearby educational, and/or tourist facilities	3
Touristic interest		
	Lack of tourist interest or no possibility of development of any type	0
	Complies with extension, accessibility, and connection even though there is no suitable infrastructure	1
	Satisfied requirements and adequate infrastructure	2
Complementary value		
	None	0
	Possibility of integration to other sites of heritage value (geological, archaeology, etc.)	1
	The site is near or integrated to other sites of heritage value, such as a national park or nature reserve	2
Community association with or public esteem for		
	Unknown associations or community values	0
	Fair: feature known by the local community	1
	Moderate: feature has some association with a local community	2
	Good: significant value for the local community	3
	High: key value for a regional or national community	4

Table 6 Socioeconomic criteria

Criterion	Grades	Points
Urban value		
	No possibility of preservation	0
	Low potential for preservation	1
	Possibility of developing a museum or site interpretation center	2
Mineral value		
	None	0
	Fossils found in abandoned mines	1
	Fossils found in mineral exploitation	2
Public works		
	None	0
	Possibility of heritage rescue	1
	Able for heritage rescue and to develop an interpretation center	2

of taxa, are very important for paleontological and environmental reconstructions.

Type Localities Type localities are those from which certain species have been first recognized and defined taxonomically.

Taphonomic Information Sites with unusual taphonomic processes or which represent unaltered paleobiological communities are of very high paleobiological importance. It could also includes large monospecific assemblages, low on diversity but very important as a means to study a population.

This criterion by itself requires an independent discussion that exceeds the objective of this article. Recently, during an international congress on geoconservation (Sharples 1995), geologists developed the concept of geodiversity. It was first used in Australia. Dixon (1996) defined it as the "the natural range of geological, geomorphological and soil features, assemblages, systems and processes; it includes evidence for the history of the Earth and a range of processes currently acting on rocks, landforms and soils" (see also Panizza 2009). Into this criterion, a large number of categories can be included. Based on those identified by Gray (2004), Hayward (2009), and Mansur and Souza Carvalho (2011), the following categories were proposed.

Geological Significance Addresses the question: "How important is the feature to the understanding of the geology or the biotic evolution of the Earth?" Scored highest are sites that are of international importance, followed by national, regional, or just significant for the understanding of local geology.

Geological Integrity of the Site It addresses the question of whether this type of site is rare and fragile and whether there has been any negative impact to the site that has diminished its paleontological values. Into this category, we recognized extensive, finite, and integrity sites. The importance of distinguishing between these three groups is that their successful management usually requires a quite different approach. As a rule, extensive sites are more robust than integrity or finite sites and can often tolerate the effects of human activities to a greater degree. The site categories are not mutually exclusive, and there are numerous examples where part of a site is classified as extensive and another part is classified as finite or integrity.

(1) Extensive sites contain geological features, which are relatively extensive both above and beneath the surface. The basic principle is that removal of material does not cause depletion or damage to the resource, as new material of the same type is being freshly exposed as material is removed. The focal management aim is to achieve and maintain an acceptable level of exposure of the features of interest.
(2) Finite sites contain geological features that are limited in extent so that removal of material may cause depletion of the resource. The features are often irreplaceable if destroyed. The basic management principle is to permit responsible scientific usage of the resource while conserving it in the long term. Hence, it is often necessary to implement controls over removal of material.
(3) The integrity of sites is also considered from a geomorphological point of view, since damage to one part of a site may adversely affect the site as a whole. In the case of active process sites, the fundamental principle is to maintain the active processes by noninterference as far as possible. National Nature Reserves may be included in this category.

Scientific Potential This criterion deals with the potential of each site to expand the information and understanding of paleontological resources through continued scientific research and new methodology.

Context Assesses whether the site is a component of a larger group of associated features. Groups of features might include a cluster of fossil sites that together span the geological period in a particular region or collectively include a range of fossils found in a widespread formation that may include different paleoenvironments or depositional facies.

Visual Contribution to Landscape The visual impact or contribution of the landform or feature in the wider landscape.

Association with Archeological Remains The history of humankind is generally valued from a scientific and sociocultural point of view. Fossils associated with archaeological

remains generally possess an exceptional importance due to their direct cultural links.

Geographic Situation Sites that are far from urban areas and have less potential for frequent use and thus lower numbers of visitors. They may also be less vulnerable to damage by development but may be more vulnerable to illegal collecting

Vulnerability to Damage Related to Fossil Collecting This criterion should be applied in conjunction with the concept of fragility and accessibility. An extensive locality, which is not easily destroyed, would be less vulnerable (Norman 1992). Furthermore, the destruction by collecting is easier when many people visit the site and by the manner in which overburden is removed and excavations take place.

The educational criteria focus on the sites' potential to interpret the feature and enhance public understanding and appreciation of its fossil significance. The assessment process includes the visibility of features, the feasibility of public access, and the proximity to educational facilities or tourist areas.

Historic Value Sites which form part of the history of paleontology. In general, it concerns sites which were discovered in the early days of this science (e. g. pre-1900).

Educational Interest The potential of a site for being an object of formal and nonformal educational activities, university-level teaching, congress visits, etc. is considered.

Tourist Interest Similar to the previous criterion but including sites of potential or actual value to groups interested in the fossil record. We evaluate the possibility of sustainable use and tourism and how the site may impact social interest aroused by its fossils (Morales and Gómez 2000).

Complementary Value Sites of complementary value are those located in areas already protected for its cultural or natural significance and, therefore, can be used in a complementary way.

Community Association With or Public Esteem For Sites which have a spiritual, cultural, customary, religious, social, political, philosophical, aesthetic, or economic value for an ethnic, local, or wider community (Hayward 2009).

Urban Value Refers to sites located in urban areas or lands potentially available for development. In attempting to protect such areas, alternative solutions are proposed, such as rescue excavations or the incorporation of these sites into parks, gardens, or "in situ" museums.

Mineral Value In the case of sites found in association with mineral exploitation, fossil excavation can sometimes only be realized as long as mineral extraction continues. In other cases, however, ongoing work may easily destroy the fossil concentrations if deposits have a limited extent and thus require a salvage program to collect the fossils and place them in a museum.

Public Works As in the preceding case, public works can destroy the sites or can be a potential source of finding new sites.

Final Remarks

In Argentina there are some public policies designed to integrate natural and cultural heritage in territorial planning (e.g. Ministerio de Planificación Federal 2004); however, there is no general consensus on the methodological tools needed to accomplish this goal. In this sense, it would be appropriate to introduce the categorical system of the landscape—rather than the site—as a paleontological heritage management unit. It would also be useful to take into account a number of evaluation criteria in order to identify, preserve, safeguard, and disseminate paleontological heritage.

We proposed a scheme of criteria in which the scores of all site criteria are summed. In this scheme, the sites that obtain at least 25 points are eligible to be placed in the group that needs public policy to ensure their preservation and conservation. To illustrate this, we have calculated the scores for each category in two emblematic sites of the Argentine record: Gran Barranca of Colhue-Huapi lake in Patagonia (8+7+4+2+8=29) and Ischigualasto and Talampaya National Park (9+8+6+7+15=45). For both localities, we have estimated a score above 25 points, but the differences between both are a reference when establishing a public policy of heritage preservation. The overall value in this example is relative; it is important that each category can be used for decision making in relation to a specific problem, e.g., sites that require urgent conservation and protection action.

It is worth recalling that the main goal is not only for the protection of the assets of the past but also the sustainable management of the past, in the present, for the future. Thus, the challenge is not how to leave the landscape unmodified but how to maintain and recreate it for the interest of science as well as for public enjoyment. This could not be achieved unless different levels of government, private companies, professionals, and the community at large join together to plan rural and urban areas developed in such a way that the physical evidence of the past remains visible and legible. This strategy is also the starting point for planning and

implementing practical conservation and protection measures, including landscape monitoring and enhancement.

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