



Geodiversity: The Natural Support System of Ecosystems

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Abstract

Geodiversity, the diverse range of properties and processes of the abiotic natural world, provides services which support biodiversity, thus geodiversity is intrinsically linked with ecosystem services (ES). Many countries have adopted strategies and frameworks for identifying sites that exhibit valuable geodiversity and have implemented measures for conserving them, including recognition of their distinctive nature within the planning process. However, there is no international legislation enforcing protection of geodiversity, and since there is much spatial variability in the services provided the responsibility for identifying sites and informing planning policies is often devolved to local bodies. This has resulted in a variety of approaches, so this chapter offers a broad framework for formulating geodiversity action plans, carrying out site audits and assessing the value of sites in terms of their geosystem services. Useful resources for both theoretical and applied geodiversity practice are identified and the examples of geosite assessments in this chapter can be expanded and adapted to suit user requirements in order to demonstrate links to ES and planning.

Keywords

Geodiversity · Geoparks · Action plans · Site audits

16.1 Introduction to Geodiversity

Geodiversity refers to the variety of abiotic nature that is the non-biological part of the natural world. It has been defined by Murray Gray (2004: 8) as:

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the natural range (diversity) of geological (rocks, minerals, fossils), geomorphological (landforms, processes) and soil features. It includes their assemblages, relationships, properties, interpretations and systems.

To better appreciate the value of geodiversity Gray asks the reader to imagine a landscape lacking in such variations and conjures an image of a hypothetical smoothly spherical earth where the landscape is monotonously flat and so without mountains, valleys and deep basins occupied by seas; the rock type is homogenous so lacks a variety of goods such as minerals, building materials or hydrocarbons. Capacities such as the ability to store water, weathering of diverse rock types to produce a variety of soils for growing different crops or supporting different ecosystems also lack variety.

Diversity in the abiotic (geo) world is therefore intrinsically linked with ecosystem services and landscape planning. As illustrated in Fig. 16.1 it underpins many types of provisioning or regulating services (e.g. those relating to food production and supply of materials, see Chap. 10), as well as providing the medium which hosts biotic nature (Chap. 18). In addition to these indirect associations, geodiversity directly supplies other services and benefits, including those associated with scientific knowledge, human experience of landscapes and use for recreational activities.

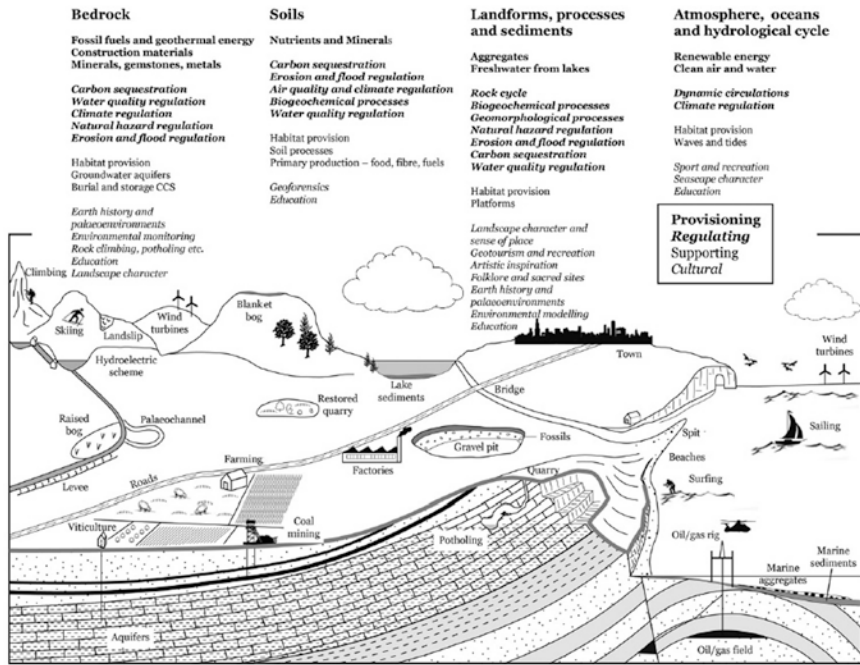


Fig. 16.1 Examples of goods and services derived from geodiversity (Gray et al. 2013, permission to reproduce kindly granted by Elsevier)

The recognition of the importance of geodiversity in landscape planning has increased rapidly during the past decade (Gray 2009). However, awareness of the services associated with geodiversity lags behind those for biodiversity, possibly because the geosphere is perceived as more robust and durable so not requiring conservation. Nevertheless, the importance of the connection between the geosphere and biosphere has received more attention in landscape planning and criteria such as endangerment or rareness are being used to prioritize protective or management actions with respect to geodiversity.

16.2 Planning and Implementation Framework

Examples of individual areas being designated because of their geological or geomorphological features can be traced back to the nineteenth century. For instance, one of the earliest nature conservation initiatives in Germany (1836) sought to protect the silhouette of the Drachenfels mountain. However the first global initiative for geoconservation did not occur until 1972 at the United Nations, Educational, Cultural and Scientific Organisation (UNESCO) World Heritage Convention when 189 UN member states signed a treaty to conserve sites of:

cultural and/or natural significance which is so exceptional as to transcend national boundaries and to be of common importance for present and future generations (UNESCO 2013: Para 49).

Specific reference to geological and physio-graphical formations ensured geoconservation of World Heritage Sites such as the Veneto mountains in the Dolomites (Italy), Surtsey volcano in Iceland and the Great Copper Mountain in Falun (Sweden).

The value of geodiversity at regional and local scales was given more recognition when the European Geoparks Network was established in 2000 (subsequently extended as a global network). The adoption of Recommendation Rec(2004)3 by the Council of Europe Committee of Ministers placed further responsibility on member states to identify and manage areas of special geological interest. European Geoparks such as the Vulkaneifel European Geopark (Germany) and Parco di Madonie (Italy) have since flourished. These policy developments at the EU level have been driven by a combination of bottom-up efforts by local and regional bodies and pan-national organizations such as ProGeo (the European Association for the Conservation of Geological Heritage, <http://www.progeo.se/>). ProGeo has been particularly effective in translating recommendations into actions and as a driving force working with the International Union for Conservation of Nature (IUCN) and the United Nations Educational, Scientific and Cultural Organization (UNESCO, which manages important World Heritage Sites and Global Geoparks, <http://whc.unesco.org/en/list>) to promote geoconservation and integration with nature conservation. However, the degree to which individual European countries have adopted geodiversity in landscape planning, embraced geoconservation and declared new geoheritage sites varies considerably.

An international milestone was reached in 2008 when for the first time in its 60 year history the IUCN adopted a resolution relating to the Conservation of Geodiversity and Geological Heritage. It is probably no coincidence that the United Nations General Assembly proclaimed 2008 to be the International Year of Planet Earth, initiated jointly by the International Union for Geological Science (IUGS) and UNESCO in order to (World Conservation Congress 2008: 102):

increase awareness of the importance of earth sciences in achieving sustainable development and promoting local, national, regional and international action

[and emphasizing]

that geodiversity, understood to include geological and geomorphological diversity, is an important natural factor underpinning biological, cultural and landscape diversity, as well as an important parameter to be considered in the assessment and management of natural areas.

Contrary to biodiversity protection, there is no international legislation covering geodiversity and consequently at this level there are no frameworks, standards or guidelines on procedures for measuring, recording and valuing geodiversity. However, several European Directives and Conventions require an understanding of the functional support and underpinning that geodiversity provides for biodiversity and landscape, for example the Habitats and Species Directives, the Water Framework Directive, the Floods Directive and the European Landscape Convention. In addition to IUCN, UNESCO and ProGeo there are several international organizations supporting geodiversity, for example the Committee of Ministers of the Council of Europe, the Nordic Council of Ministers, the European Federation of Geologists (EFG, www.eurogeologists.de), International Association of Geomorphologists (www.geomorph.org) and Coastal and Marine Union (Eucc, www.eucc.nl/en/).

An increasing number of EU countries have included geoconservation in policy frameworks, two examples being the revision of the Spanish National Law on Protection of Natural Areas and Wildlife (Carcavilla et al. 2009) and guidance published for England (<http://publications.naturalengland.org.uk/category/30050>). Such legislation and official documents provide a basis for incorporating considerations regarding geodiversity and associated ecosystem services into landscape planning, spatial planning and environmental impact assessments. This can be achieved through a variety of mechanisms including designating areas for protection, considering geodiversity in land use zoning strategies and investing in infrastructure to support the development of geosites for recreation and tourism purposes. Implementing such strategies typically requires the application of assessment criteria to identify priorities on a regional scale, but also with regard to how unique specific features may be on a national, European or even global scale. This is particularly true if the nature of the geodiversity is such that it has implications for recreation and tourism, in which case methods to estimate monetary use and non-use values may also help in the assessment of options.

16.3 Assessment Framework

There are no EU frameworks for geodiversity assessments, thus countries may implement their own guidelines for auditing and assessing sites for geodiversity value. In practice the available guidance varies greatly in scope and content. Ideally, each country will have a National Geodiversity Action Plan (GAP), which both feeds into and is fed by local plans – people tend to engage more readily in initiatives that have a local (and therefore directly relevant) impact rather than those at a less tangible national scale. The importance of localness was emphasised in Agenda 21 which was agreed at the United Nations Conference on Environment and Development (UNCED) Summit in 1992 and has been very influential in environmental planning. The aim of local GAPs is to formulate a management framework for observing, conserving and enhancing the valued geology, landforms, soils and associated earth heritage features within a defined area (e.g. as agreed by local government or other statutory organizations).

Figure 16.2 sets out a typical sequence of steps for the development of a Local Geodiversity Action Plan (LGAP) which meets policy requirements, but is tailored



Fig. 16.2 A framework for developing and implementing a Local Geodiversity Action Plan

to the needs of identified stakeholders and local geo-diversity processes and properties. Whilst most LGAPs are written by local interest groups, increasingly organizations whose industries utilize geo-goods are adopting GAPs. For example the UK's Department for Environment, Food and Rural Affairs (DEFRA) was funded by the aggregates sector to draw up a GAP for that industry (Thompson et al. 2006). There are a range of useful documents in the English language readily available online which provide guidance on setting up GAPs. At the strategic level these include the UK Geodiversity Action Plan (Burek and Potter 2006, <http://www.ukgap.org.uk/>) and a good practice guide by Prosser et al. (2006) which is available from the Natural England web-site listed in Sect. 16.2 above).

The key deliverable of LGAPs is to identify sites that have properties and processes providing services of such value that conservation is required. The aims and objectives of geoconservation should be clearly defined by the partnership, with key criteria likely to include quality, rareness and value of the site properties and landscape elements. The specific criteria are usually decided by the partnership in the context of abundance and quality of similar properties in the area covered by the LGAP. Where properties are also considered of value on a broader scale, such as national or international, the site may be considered as a candidate for higher level conservation such as SSSI, or World Heritage Site.

A LGAP may include information on, and examples of, sites which typify the geodiversity which characterizes the area, examples of existing geo-conservation sites and future priorities such as developing partnerships and education opportunities. An example for one county in the UK is provided by Holt-Wilson (2011) and a review of UK experience is given by Dunlop et al. (2018).

Geoconservation sites are typically identified through a clearly defined and sequential process. As illustrated in Fig. 16.3 this commences with identification of potential sites, progressing through site audit and selection for conservation, to geosite designation through a statutory or non-statutory framework and site conservation, positive management and promotion.

The next section provides an example of the audit and evaluation processes. This procedure is also applicable to audits of existing geoconservation sites as part of management plans to monitor and report on changes in their state.

16.3.1 Identifying and Characterising Geodiversity

A general framework by which a geosite is evaluated will include diverse criteria for site assessment, ranging from uniqueness and quality of the site geodiversity through social and aesthetic values, to importance in relation to capacity for supporting ecosystems services (Table 16.1).

Where a location is a potential candidate as a geodiversity site the evaluation will follow an agreed audit of properties and processes that is typically developed at regional or local level. The methods involved will vary widely depending on the criteria employed and extent of existing databases, but site selection typically involves both desk and field work, a typical audit form will include recognition of how the geosphere supports ecosystem services, for example:

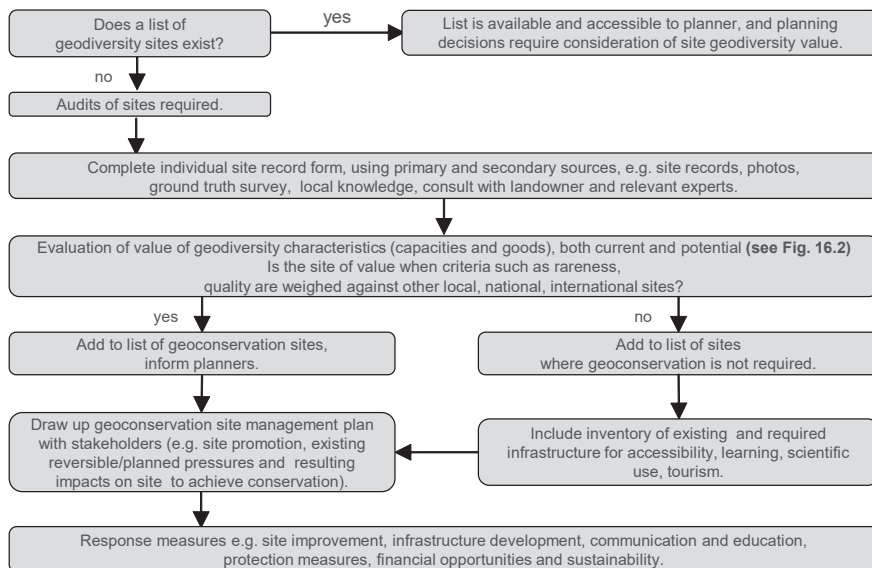


Fig. 16.3 Typical workflow to identify priority geoconservation sites

Table 16.1 Examples of criteria used to assess site geodiversity with details of methods and data sources that can be employed

Criteria	Parameters	Evaluation standards	Sources and methods
Rareness, endangerment, quality	Frequency and proportion of geosite properties and/or processes, quality relative to similar occurrences	Occurrence, existing recognition and protection (e.g. SSSI), statistical analysis	GIS analysis, existing data bases, historical and geological maps
Cultural, heritage value	Age, continuity of land use, historical connections	Existing recognition and protection, reputation	Published records and reports, measurable assets
Economic, social, aesthetic value	Willingness to pay, measurable revenue, accessibility	Frequency of use, footfall, monetary revenue, popularity	Surveys, published records and reports, publicity material
Benefit to education, science	Derived learning, contribution to scientific understanding and research	Derived learning, value to science	Educational bodies, scientific publications and citations
Ecosystem service provider	Dependence of a valued ecosystem service on a geosite	Extent of ecosystem service dependence, and the value of dependent ecosystem services	Ecosystems service records and reports

- Site status e.g. site conditions and threats, current and historic use, site description, any existing designations or conservation (e.g. of wildlife status).
- Geofeatures e.g. quantitative and qualitative record of site properties and processes, such as the geology, paleontology, soil characteristics, water, and geomorphology.
- Other features e.g. educational value, historical information, archaeological records, any particular cultural, wildlife, aesthetic and recreational attributes, references for sources of information.

The geosite services may well not be identified as ‘capacities’ and ‘goods’ on the sorts of site audit forms currently in use; they are more likely to follow a version of a popular classification of geosystem services (e.g. Gray 2011). As part of the audit process the current *and* potential beneficiaries should be identified, including organizations, public bodies, societies, industries and local communities who already, or in future, may benefit from geological and geomorphological conservation. When identifying possible future beneficiaries of the geosystem services at a site Prosser et al. (2006) suggest the following as examples:

- Those involved in geological and geomorphological research, seeking to understand the earth and the environmental change impacting on it.
- Geologists working in those industries seeking to find, utilise and manage mineral and water resources, or manage the natural environment.
- Land owners, land managers, public utilities, planning authorities and others, who require some understanding of geology, geomorphology and landscape planning, to better inform their decisions and actions.
- Ecologists, and those involved in nature conservation more generally, who need some understanding of geology, to help, for example, in planning habitat recreation projects.

Following the site audit there should be an evaluation of the value of the identified capacities and services which, when summed and compared to other local sites, form the basis of a decision as to whether the site should be recommended for geoconservation. Whilst the method for measuring and expressing the overall value of a site varies in practice, judgments usually include quantitative and qualitative indicators of the overall state, including the uniqueness, quality, condition and potential worth of each property and process in terms of its services. The value assessment process is likely to, and should, vary to reflect relevant local values, but where possible the degree of subjectivity should be minimized and the steps involved in arriving at a final assessment should be transparent.

16.3.2 Valuation of Geosite States and Impacts

The priorities assigned to different properties and services are likely to vary between GAPs, but should be transparent in the workflow for identifying geoconservation

	1 Present	2 Fair	3 Good	4 V Good	5 Outst	n/a	Don't know
SCIENTIFIC VALUE							
▪ Stratigraphy							
Time zones represented							
Stratotype present							
Major unconformity							
▪ Lithology / rock types							
▪ Sedimentary structs							
▪ Palaeontology							
▪ Landforms							
▪ Geomorpho processes							
▪ Minerals							
▪ Archaeology							
▪ Soil features							
▪ Tectonic and other							
▪ Published refs							
CULTURAL VALUE							
Earth Science assoc							
Economic / built envt							
History & folklore							
Landscape & aesthetic							
GEODIVERSITY VALUE							
Uniqueness at county level							
USABILITY							
Physical accessibility							
Free public access							
Condition e.g. overgrown							
Known hazards							
Amenity / leisure use							
EDUCATION VALUE							
Primary Schools							
Secondary Schools							
Tertiary Level							
General Interest Groups							
SUBTOTALS							
SCORE							
EXISTING DESIGNATIONS	SSSI geo	SSSI bio	GCR	RIGS	CWS	Other	
RECOMMENDATIONS	National designation SSSI geo <input type="checkbox"/> County designation CGS <input type="checkbox"/> Local geosite only <input type="checkbox"/> Get more information <input type="checkbox"/>						
Reasons / comments	<input type="text"/>						

Fig. 16.4 An example site evaluation form. (Source: Norfolk Geodiversity Partnership)

sites (Fig. 16.4). Assigning a relative worth (e.g. on a scale of 1–5) to the various capacities and goods (e.g. scientific value, cultural value) identified in each site audit should be a stage that is distinct from the audit itself in order to provide clarity.

Using such ratings also helps to facilitate future site surveys where site characteristics may not change but their value does; a separate assessment stage will allow changes in state over time to be measured. In addition, the evaluation methods and

assessment criteria should be standardized to facilitate intra- and inter-geosite comparison at least within a LGAP area. These assessment criteria are likely to include degree of rareness and quality of the site, noting both the current and potential values. An example assessment form is shown in Fig. 16.4 where a score of 4 or more for any characteristic qualified a site for recommendation as a Local Geoconservation Site.

Whilst ratings such as the 1–5 scale in Fig. 16.4 are easy to use they also embed the user's opinions about rareness, quality and other attributes, a part of the assessment that ideally should be transparent. For some services (e.g. amenity and leisure use) alternative metrics such as access payments may be possible. Bruschi et al. (2011) reviewed the range of values given by experts to various geodiversity sites and found a broad commonality in the weightings employed, but also noted there was difficulty creating a completely objective methodology that would be widely applicable. As a general rule, consulting experts where there is an agreed lack of expertise amongst the assessors and formulating a reference set of weightings based on the LGAP priorities are likely to help improve transparency and reduce user subjectivity.

When all site attributes are weighted and summed the total value is a good indication of the site suitability for geoconservation and the contributing values help to identify the important features for site management plans. For instance, recreational value could be quantified by monitoring payments at a designated car park, visitor numbers, or questionnaires which determined a willingness to pay to visit the site. In assessing the overall value of recreation a low weighting might be applicable if there were numerous sites of similar tourist attraction in the area. However, if a geosite is an exemplar for a particular geological formation then a high value weighting for scientific interest would be appropriate and could mean that it was identified for conservation even if it scored lowly on all other categories.

To increase the rigour of the assessment process, statistical methods may be applied, either in addition to or instead of weighting of values. Benito-Cavlo et al. (2009) used GIS to classify climatic, geological and land surface characteristics in the Iberian peninsula and compared several statistical techniques (Shannon's Index, Simpson's Index, Patch Richness Density) to assess regional geodiversity. They found that while the Patch Richness Density undervalued the geodiversity, the Shannon and Simpson indices were reliable as an objective evaluation of the *relative* regional geodiversity and so allowed a large area to be rapidly assessed. Experience with audits suggests that many sites have features of local interest so such techniques can be of particular value in identifying the top geoconservation priorities in regional or national planning frameworks.

16.4 Examples of Geosite Audits and Management

As the implementation of geosite audits and assessments depends appreciably on the sources of available information and the nature of any survey, three case studies are provided here to illustrate different approaches.

16.4.1 Case Study 1: GIS Audit

Where an audit is a review of site characteristics as part of an established monitoring programme there are likely to be many sources of readily available information, for example in a Geopark there will be data on footfall and opportunities for surveys to obtain quantitative values on the site as a tourist attraction (see Webber et al. 2006 for an assessment of the social and economic value of UK geodiversity). At the other extreme an audit may be a primary evaluation of a large, remote and inaccessible area with little existing data so a more suitable approach could be remotely sensed data collected by satellites with analyses using GIS software.

An example is provided by Hjort and Luoto (2012) who conducted a geodiversity audit of a remote and large area in Finland (Fig. 16.5). As ground truthing was impractical and primary data were lacking the authors used GIS processing and statistical techniques to explore relationships between numbers of geodiversity features and landscape variables (e.g. elevation, slope, solar radiation). Capacities and goods were not explicitly identified, but secondary data sets regarding services such

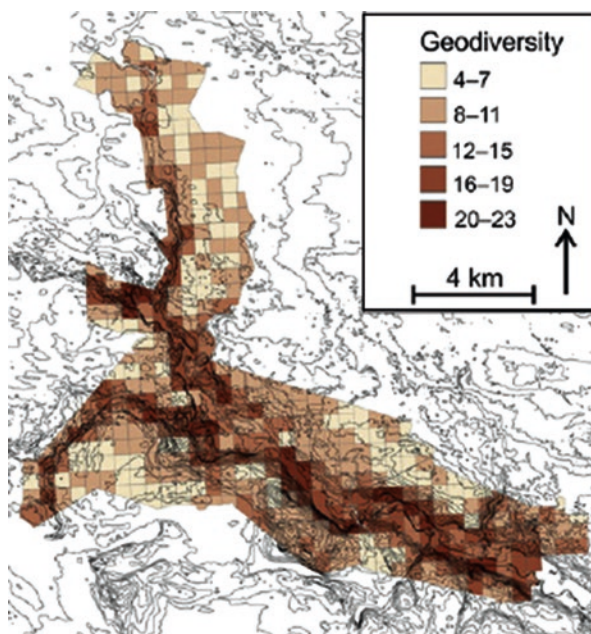


Fig. 16.5 Case Study 1: Can geodiversity be evaluated from space using GIS? The figure shows spatial patterns of geodiversity features in northern boreal Oulanka, Finland, with the legend illustrating the number of different features per cell. (Hjort and Luoto 2012, Fig 2, permission to reproduce kindly granted by Elsevier). The authors draped remote sensed data on bedrock geology, geomorphology and hydrology over a DEM to measure topographic heterogeneity. Multivariate statistical techniques were applied to evaluate relationships with geodiversity and mapped a range of features including springs, tors, sandbars and deflation surfaces

as agricultural cropping and water resources were generated. This example suggests that geodiversity may underpin connections between capacities and goods.

16.4.2 Case Study 2: Site Assessment in a Landscape Context

The assessment of state or impacts at a site scale may require consideration of processes operating across a larger geographical area. For instance, Stace and Larwood (2006) discuss the impact of agricultural drainage and activity on the distinctive peat soils and landscape of the Fenlands in eastern England. Inappropriate land management has resulted in breakdown of the organic matter that makes up the bulk of these soils, resulting in loss of mass and wind erosion that potentially limits their agricultural capacity. The impacts extend over a wide area as the blown soils are carried in the atmosphere and can discolour water bodies, requiring additional treatment of abstracted water used for human consumption. Resolving these issues requires changes in farming practice to conserve the peat soils and protect water resources. Responses to impacts and the management of capacities and goods in the context of a broader landscape planning framework is further discussed in Chap. 19.

16.4.3 Case Study 3: Geosite Management

The Giant's Causeway in Northern Ireland is a World Heritage Site valued for the striking basalt rock exposures. The site supports protected flora and fauna, as well as having many cultural associations. As a result of a fire at the site management plans were revised to improve education and visitor awareness of the geological features and this has improved visitor understanding, demonstrating the benefits of including review and revision of strategies within geosite management plans.

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