



**Enhancing global nature conservation by integrating  
geodiversity in policy and practice**

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# Enhancing global nature conservation by integrating geodiversity in policy and practice

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Flora and fauna are commonly in the spotlight in nature conservation. However, geodiversity, the richness of the Earth's surface and sub-surface features and processes, has gained increasing attention in research (Schrodt et al., 2019) and conservation management and practice (Crofts et al., 2020; Brilha, 2022). Geodiversity is essential for sustaining biodiversity (Beier et al., 2015; Schrodt et al., 2019) but is yet not in the mainstream of nature conservation policy and practice (Brilha & Reynard, 2018; Schrodt et al., 2019; Chakraborty & Gray, 2020; Crofts, 2022). After outlining the important role of geodiversity, and progress in recognizing it in policy so far, we herein suggest a four-step plan towards consistent consideration of geodiversity for the benefit of nature: Promotion-Collaboration-Integration (policy)-Implementation (practice).

In 2015, there was a *Conservation Biology* Special Section dedicated to geodiversity in biodiversity conservation (Beier et al., 2015). The framework of Conserving Nature's Stage (CNS) was introduced: that geodiversity forms the stage for actors (organisms) – the more diverse the stage, the more diverse the actors. This is because diverse abiotic conditions create many niches and microhabitats for different species, offering a range of ecosystem functions, even as the wider environment changes (Beier et al., 2015). The range of environmental conditions also creates opportunities for two-way interactions between species and the physical environment (Viles, 2020). Empirical works support the existence of a geodiversity-biodiversity relationship at various spatial scales (Tukiainen et al., 2022).

Geoconservation is actively advanced at the international level (Brilha, 2022), with geosite assessments readily conducted (Brilha & Reynard, 2018). Leading nature conservation

25 organizations, including International Union for Conservation of Nature (IUCN), have recognized  
26 the role of geodiversity and geoconservation in their own right, and for their benefits to biodiversity  
27 (Crofts et al., 2020). One key step has been the explicit mention of geodiversity in the revised IUCN  
28 categories of protected areas (Dudley, 2008). IUCN members and the Geoheritage Specialist Group  
29 of the World Commission of Protected Areas (WCPA) are currently defining the methods, criteria,  
30 standards and governance to be applied as Key Geoheritage Areas, which would complement the  
31 Key Biodiversity Areas programme (Brilha, 2022). The Global Geoparks Network has grown from  
32 17 European and 8 Chinese Geoparks in 2004 to 177 UNESCO Global Geoparks across 46  
33 countries (as of October 2022).

34 Despite the growing recognition of geodiversity and geoconservation, they are still lagging behind  
35 biodiversity in mainstream nature conservation (Brilha & Reynard, 2018; Schrodtt et al., 2019).

36 While excellent examples of geodiversity recognition exist for some countries, territories, and sites  
37 (examples in Table 1), it is not something that is acknowledged as a matter of routine. Yet,  
38 geodiversity features are susceptible to damage by human activities (Crofts et al., 2020). For  
39 instance, deterioration of Natural World Heritage Sites listed under criterion (viii) “geology” has  
40 been reported (Osipova et al., 2020). According to CNS, geodiversity may also play a vital role in  
41 supporting biodiversity in a changing climate. This is because the stage, or physical environment,  
42 may have greater resilience in the face of climatic changes compared to biological communities  
43 (Beier et al., 2015; Comer et al. 2015).

44 Thus, it is important to ask: (i) what are the means by which geodiversity can be better recognized?;  
45 and (ii) how can geodiversity conservation be better integrated as an important component and  
46 target of nature conservation policies and practice? From our perspective, the major challenge is to  
47 raise awareness of the significant role of geodiversity and have this formalized in conservation  
48 planning, which will then inform practical management efforts. Successful policy requires societal  
49 and political will, as well as evidence and knowledge of the practical steps and tools. Therefore, for

50 tackling this challenge, we suggest four important steps, summarized as ‘PCII’: Promotion-  
51 Collaboration-Integration-Implementation.

52

53 *Step 1: Promotion of the importance of geodiversity for nature conservation at different scales*

54 The first step is to justify and share information about the importance of geodiversity in itself and  
55 for living nature, asking and answering the question “why do we need to recognize geodiversity in  
56 the current nature conservation context?” across different audiences. In promoting geodiversity, it is  
57 useful to highlight its role in ecosystem service provision (Chakraborty & Gray, 2020) and its  
58 contribution to United Nations Sustainable Development Goals, such as 6 (clean water and  
59 sanitation) and 15 (life on land; e.g., by introducing the CNS strategy) (Gray & Crofts, 2022).  
60 Events like the World Biodiversity Forum and International Geodiversity Day (6<sup>th</sup> October) present  
61 prime opportunities for promotion.

62

63 *Step 2: Collaboration between relevant stakeholders in policy, wildlife conservation, protected area*  
64 *management, geoconservation, and local communities*

65 The second step is to increase communication and collaboration between different stakeholders  
66 involved in biodiversity conservation and in geoconservation, such as between local communities  
67 and policymakers, or among researchers from different disciplines such as geology, geography and  
68 ecology. Efforts could focus on the topics highlighted in the *Conservation Biology* CNS Special  
69 Section (Beier et al., 2015), such as testing the effectiveness of CNS (especially at fine spatial  
70 scales), exploring the vulnerability of various geodiversity features to climate change, and  
71 scrutinizing how geodiversity conservation can best support ecological and evolutionary processes.  
72 Steps towards aligning different stakeholders are being made in science (see e.g., Anderson et al.,  
73 2015; Schrodtt et al., 2019; Gordon et al., 2022) and in practice (such as the work done by different

international organizations, e.g., International Union of Geological Sciences, ProGEO, IUCN and UNESCO), but there is space and need for more. In addition to collaboration between different organizations and other stakeholders, it is important to advocate discussion within major nature conservation organizations. For instance, there could be a joint task force between the IUCN WCPA and the IUCN Commission on Environmental, Economic and Social Policy to investigate stakeholder involvement, or with IUCN Species Survival Commission to reveal practical possibilities of geodiversity in the conservation of at risk species.

81

### *Step 3: Integration of geodiversity into global and national policy frameworks*

For the integration of geodiversity into policy frameworks and systematic conservation planning, both long-established (e.g., IUCN protected area categories), as well as newer area-based conservation approaches should be utilized (e.g., other effective area-based conservation measures; OECMs). For instance, geodiversity considerations could be incorporated into ecological gap analysis, which is a method for identifying biodiversity that is not sufficiently conserved within an existing protected area system, or through other effective and long-term conservation measures (Dudley, 2008). Across scales and locations, national policy should more explicitly require the consideration of geodiversity as an integral part of the nature conservation management and monitoring process (Gordon et al., 2022). For example, in Scotland, the Geodiversity Charter places expectations on local authorities, whilst in Tasmania, geodiversity is an equal part of Natural Heritage Strategy with biodiversity (see Table 1 for more examples).

In geoconservation, the inventory of geosites has been essential when integrating geoheritage into the management of protected areas (Mucivuna et al., 2022) across a range methods and places (Brilha & Reynard, 2018). Ongoing work by the IUCN and its Geoheritage Specialist Group on defining the characteristics of Key Geoheritage Areas offers possibilities for the mobilization of

98 local administrations and communities for enhanced geoconservation with a unified geosite  
99 evaluation framework (Brilha, 2022).

100 Meanwhile, some designated sites will be for geoconservation (e.g., a geosite or geopark). The level  
101 of legal protection for these sites is highly variable between countries, but many that offer some sort  
102 of long-term protection for geodiversity will also have biodiversity benefits because pressures from  
103 humans will be limited. In such cases, sites may be considered OECMs: i.e., biodiversity is not the  
104 focus, but is a beneficiary. OECMs are a relatively new concept in area-based conservation, but  
105 could offer a consistent mechanism for integrating geodiversity into national policy using existing  
106 IUCN guidance (IUCN-WCPA Task Force on OECMs, 2019).

107

#### 108 *Step 4: Implementation of geodiversity-biodiversity management in practice*

109 The fourth step is the integration of geodiversity into conservation management, which can be done  
110 by utilizing existing best practice in geoconservation (e.g., Crofts et al., 2020, give an overview of  
111 geoheritage management in protected areas) and biodiversity conservation (e.g., Open Standards for  
112 the Practice of Conservation, and the Conservation Measures Partnership frameworks). The  
113 implementation would benefit from a clear, practical framework for classifying and mapping  
114 geodiversity features, assessing trends in their condition, and having measurable forms of  
115 implementing and monitoring their conservation.

116 Gordon et al. (2022; see their Fig. 2) demonstrate the application of geodiversity to biodiversity  
117 conservation for protected area managers, but the approach could easily be applied outside  
118 protected areas (e.g., for OECMs). Integrating geodiversity first requires collecting data on a site's  
119 geology, geomorphology, soil, topography, and hydrology, as well as paleoenvironmental records  
120 and landscapes, as applicable. Geodiversity must then be assessed regarding features' ecological  
121 relevance and connectivity between them: these are the features that will define the site's

122 conservation objectives. Finally, geoconservation measures must be implemented to protect and  
123 manage features of conservation significance, which will require associated monitoring and  
124 consideration in the wider geographic context (e.g., connectivity), with future environmental change  
125 in mind.

126 Effectiveness should then be assessed based on guidance developed by the IUCN WCPA (Hockings  
127 et al., 2006). Effective conservation requires understanding the local social, cultural, and  
128 environmental context (e.g., links between geodiversity and biodiversity), setting objectives and  
129 planning how to achieve them, obtaining adequate resources, establishing a management process,  
130 monitoring, delivering objectives, and assessing outcomes. Ultimately, existing management  
131 effectiveness systems will need to be modified to explicitly account for geodiversity and its role in  
132 maintaining biodiversity to better reflect their close connection. This could mean, for example,  
133 monitoring a hydrological feature (e.g., a freshwater spring) or geomorphological process (e.g.,  
134 slope stability) towards measuring the effectiveness of practical efforts to reduce pressures on these  
135 features and, ultimately, the species that benefit from them.

136

### 137 *Summary*

138 Integrating geodiversity into mainstream nature conservation planning and management is essential  
139 for the sake of biodiversity, which could be better protected by recognizing geodiversity, and for the  
140 intrinsic value of geodiversity itself. We need a holistic approach to nature to safeguard both  
141 biodiversity and geodiversity. Our 'PCII' steps offer a pathway towards consistent consideration of  
142 geodiversity in nature conservation.

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193 **Tables**

194 Table 1. Examples of nature conservation policies, frameworks, tools, and legislation that acknowledge geodiversity.

Scale/extent	Location	Name	Short description	Objectives	More information (reference/link)
International	Global	United Nations Educational, Scientific and Cultural Organization (UNESCO) Global Geoparks Network	The network consists of areas that have sites of international geological significance, and which are managed with a holistic concept of protection, education and sustainable development. Geoparks promote the importance of protecting the Earth's geodiversity through actively engaging with local communities.	In the statutes of the International Geoscience and Geoparks programme, it is stated that the aim of the network is to set a " <i>mechanism of international cooperation by which areas of geological heritage of international value, through a bottom-up approach to conserving that heritage, support each other to engage with local communities to promote awareness of that heritage and adopt a sustainable approach to the development of the area</i> ".	Statutes of the International Geoscience and Geoparks programme, UNESCO General Conference, 38th Session, Paris, 2015
International	Global	World Heritage Sites	The list promotes the conservation of natural and cultural sites of outstanding universal value. To be included on the list, sites must meet at least one out of ten criteria, of which one is geology, or criterion (viii): " <i>to be outstanding examples representing major stages of Earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features</i> ". In addition, criterion (vii) acknowledges sites with high scenic value or exceptional natural beauty.	There are 11 themes introduced for guiding the application of criterion (viii): (1) History of planet Earth and the evolution of life, (2) Tectonic systems, (3) Erosional systems, (4) Volcanic systems, (5) River, lake and delta systems, (6) Cave and karst systems, (7) Coastal systems, (8) Marine systems, (9) Glacial and periglacial systems, (10) Desert and semi-desert systems, (11) Meteorite impacts.	Mc Keever, P. J., & Narbonne, G. M. (2021). Geological World Heritage: A revised global framework for the application of criterion (viii) of the World Heritage Convention. Gland, Switzerland: IUCN.
National	France	The National Inventory of Natural Heritage	A region-by-region inventory programme for the nation's geological heritage, launched in 2007 by the French Ministry of Environment.	The inventory is based on the law enacted in 2002 and which grants the formal notion of geological heritage for the first time in France (French Law 2002-276, February 27th, art.411-5): " <i>The inventory of natural heritage is set up for the entire national territory of France. A natural inventory encompasses the inventory of the richness of ecologic, faunistic, floristic, geologic,</i>	<a href="http://hdl.handle.net/10026.1/4995">http://hdl.handle.net/10026.1/4995</a>

				<p><i>mineralogical and paleontological richness</i>1. It is also defines that the inventory is conducted under the scientific responsibility of the National Museum of Natural History of France”.</p> <p>The ratified geosite data are available for public use in <a href="http://inpn.mnhn.fr">http://inpn.mnhn.fr</a></p>	
National	Norway	EcoSyst framework	EcoSyst demonstrates how to account for all of nature as part of a systematic framework, defining principles for measuring natural variation at different ecodiversity levels, considering variables that can account for variation, hierarchies, and guidelines for mapping. ‘Nature in Norway’ is the implementation of EcoSyst for Norway, with examples provided.	EcoSyst aims to provide a systematic approach to ecological diversity, explicitly accounting for biotic and abiotic nature, in the same way as we have a taxonomy for species. It aims to be globally applicable, having been demonstrated for Norway.	Halvorsen, R., Skarpaas, O., Bryn, A., Bratli, H., Erikstad, L., Simensen, T., & Lieungh, E. (2020) Towards a systematics of ecodiversity: The EcoSyst framework. <i>Global Ecol Biogeogr</i> , 29, 1887–1906.
National	Scotland (UK)	Scotland’s Geodiversity Charter 2018–2023	The Charter presents a national vision of how Scotland can better appreciate and integrate geodiversity into various aspects of conservation, policy, and society.	Scotland’s Geodiversity Charter has 96 signatories who all work towards “ <i>promotion and management of Scotland’s geodiversity and better integration of geodiversity into policy and guidance, consistent with the economic, social, cultural and environmental needs of Scotland</i> ”.	<a href="https://scotlandsgiodiversit ycharter.org/">https://scotlandsgiodiversit ycharter.org/</a>
National	Spain	Spanish Law 42/2007 on Natural Heritage and Biodiversity (Ley 42/2007, de 13 de diciembre, del Patrimonio Natural y de la Biodiversidad)	This law, which was adopted on 13 December 2013, establishes the basic legal regime for the conservation, sustainable use, improvement and restoration of natural heritage (including geodiversity and geosites) and biodiversity. The conservation of geological heritage is one of the foundations of the law. Spanish national inventory of sites of geological interest is processed in the context of the law.	As Carcavilla et al. (2009) have summarized, there are three main geodiversity-related aspects in the law: (1) specific reference to geology, the geological heritage, geoparks, and geodiversity; (2) boost for inventories and measures for the conservation of the geological heritage and geodiversity; (3) enhancement of protection mechanisms.	<a href="https://www.boe.es/buscar/ act.php?id=BOE-A-2007-21490">https://www.boe.es/buscar/ act.php?id=BOE-A-2007-21490</a>  See also the summary about geoconservation in Spain: Carcavilla, L., Durán, J. J., García-Cortés, À, & López-Martínez, J. (2009). Geological Heritage and Geoconservation in Spain: Past, Present, and Future. <i>Geoheritage</i> , 1, 75–91.

National	USA	National Parks Service Geodiversity Atlas	The Atlas provides a repository for geodiversity information across the portfolio of National Parks, explicitly identifying features and processes across geology, soil, hydrology, and geomorphology. It also provides 'Field Notes' to assist visitors, educators, and students.	The Atlas actively recognizes and promotes geodiversity through by allowing people to easily engage with geodiversity across the country. Information from the Atlas is used to support management of geodiversity and biodiversity.	<a href="https://www.nps.gov/articles/geodiversity-atlas-map.htm">https://www.nps.gov/articles/geodiversity-atlas-map.htm</a>
Sub-national	Andalusia (Spain)	Andalusian Geodiversity Strategy (Estrategia Andaluza de Gestión integrada de la Geodiversidad)	A strategy which establishes mechanisms for the conservation, promotion and sustainable use of geological heritage in Andalusia area. Includes an Andalusian Geosites Inventory, conducted in 2011.	The objectives of the strategy are: (1) Definition of an institutional policy and model for integrated geodiversity management; (2) Guarantee geoconservation in Andalusia; (3) Promote geotourism in Andalusia; (4) Strengthen education and training for conservation and geotourism; (5) Promote participation in international programs; (6) Assessment and monitoring of the action plan.	<a href="https://www.juntadeandalucia.es/medioambiente/porta/landing-page-planificacion/-/asset_publisher/Jw7AHImcvbx0/content/estrategia-andaluza-de-gesti-c3-b3n-integrada-de-la-geodiversidad-2/20151">https://www.juntadeandalucia.es/medioambiente/porta/landing-page-planificacion/-/asset_publisher/Jw7AHImcvbx0/content/estrategia-andaluza-de-gesti-c3-b3n-integrada-de-la-geodiversidad-2/20151</a>
Sub-national	Tasmania (Australia)	Natural Heritage Strategy for Tasmania (2013–2030)	A strategy which guides conservation and management of Tasmania's natural heritage. It provides directions for nature conservation programs managed by the Department of Primary Industries, Parks, Water and Environment. The strategy is based on a landscape approach, that accounts for biodiversity and geodiversity (so, natural heritage) in both terrestrial and aquatic environments.	There are four goals in the strategy: (1) Tasmania's biodiversity and geodiversity values are identified, understood and conserved; (2) All stakeholders and the community have the opportunity to support and protect natural heritage; (3) Tasmanians experience social, economic and environmental benefits from sound landscape scale conservation and management; (4) The Natural Heritage Strategy is implemented in a coordinated, efficient and effective way that achieves measurable results, and improves through experience.  A Tasmanian Geoconservation Database is used as a planning tool in land management and in assessing development proposals, and it can be accessed in: <a href="https://nre.tas.gov.au/conservation/geoconservation/tasmanian-geoconservation-database">https://nre.tas.gov.au/conservation/geoconservation/tasmanian-geoconservation-database</a>	<a href="https://nre.tas.gov.au/conservation/natural-heritage-strategy-(2013-2030)">https://nre.tas.gov.au/conservation/natural-heritage-strategy-(2013-2030)</a>  See also the summary about geoconservation in Australia: Cresswell, I.D. (2019). Geoheritage and Geoconservation in Australia. <i>Australian Journal of Earth Sciences</i> , 66, 753–766.
Local	Grand Canyon National Park (GCNP),	Grand Canyon National Park: Geologic Resources Inventory Report	The GCNP is a keystone in the USA National Park System, a World Heritage Site and one of the seven natural wonders of the world. It is especially known for its geologic landscapes and geologic	The report provides geological map data and pertinent geologic information to support resource management and science-informed decision-making, and it is conducted for the natural resource parks through the USA National Park system. The purpose of the GCNP is to preserve and protect Grand Canyon's unique	Graham, J.P. (2020). Grand Canyon National Park Geologic Inventory Report, Natura Resources Report

	Arizona (USA)		resources, which are extensively scrutinized in the Inventory Report.	geologic, paleontologic and other natural and cultural features, as well as to provide the public opportunity to experience Grand Canyon’s outstanding natural and cultural features, and to protect and interpret Grand Canyon’s extraordinary scientific and natural values.	NPS/NRSS/GRD/NRR – 2020/2195
Local	Northumbe rland National Park, England (UK)	Northumberland National Park: Geodiversity Audit and Action Plan	The plan addresses the varied facets of geodiversity in the National Park and adjoining area. It provides practical suggestions (e.g., objectives and related actions, the list of geodiversity sites) for the increased protection of and enhancement of geodiversity and encourages the involvement of local community. It is made to complement the policies for the protection of wildlife, cultural and historical issues.	Altogether, there are 11 objectives and 49 related actions that the plan sets out. An example of an objective and related action:  Objective 5. Geodiversity of active quarries.  Action 6.1 Encourage Quarry Operators to prepare quarry specific Geodiversity Action Plans  Action 6.2 Seek opportunities to report, record, conserve and enhance geodiversity in active quarries	<a href="https://nora.nerc.ac.uk/id/eprint/7493/1/CR07037N.pdf">https://nora.nerc.ac.uk/id/e print/7493/1/CR07037N.p df</a>