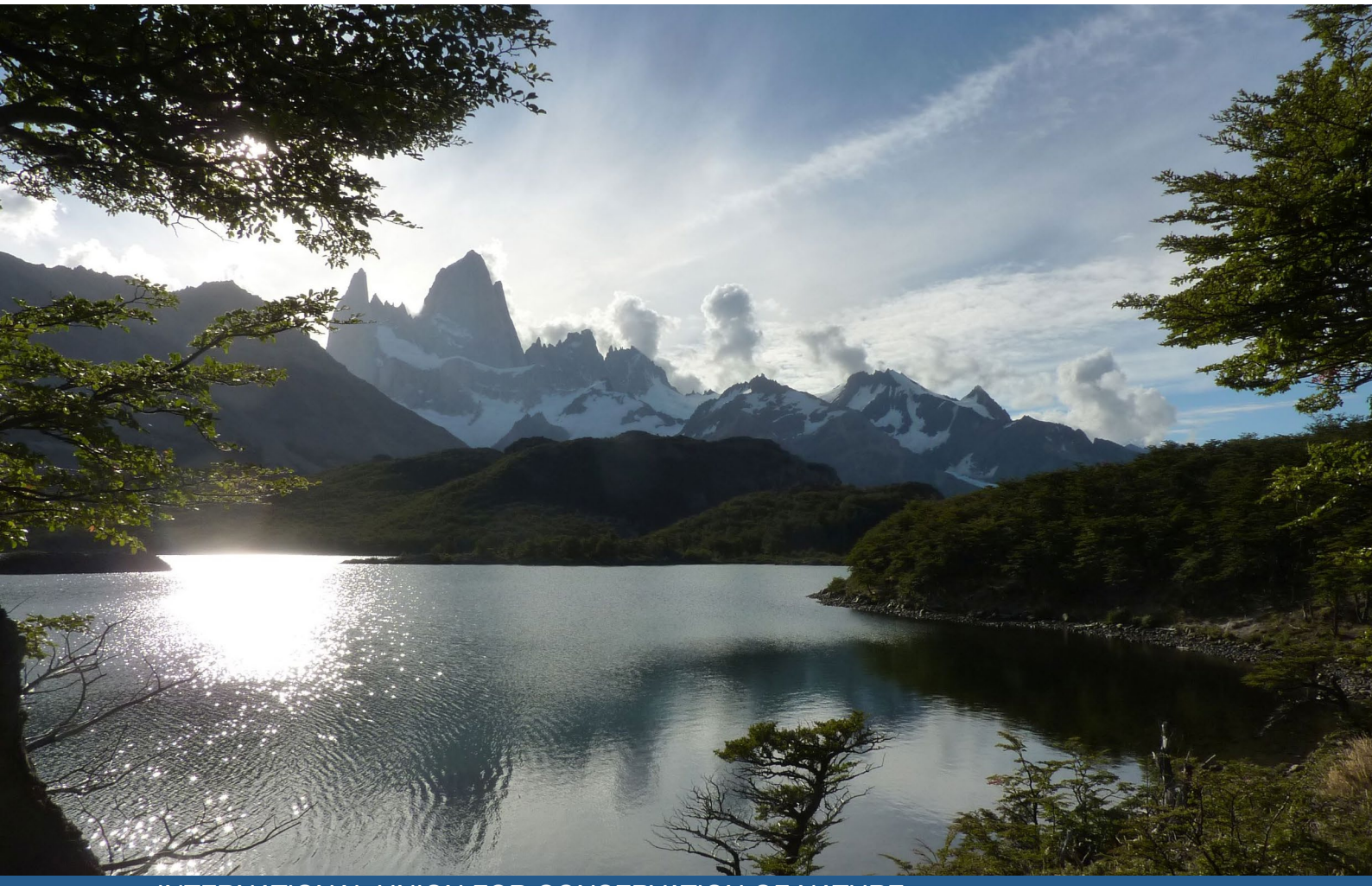
Geological World Heritage

A revised global framework for the application of criterion (viii) of the World Heritage Convention

Patrick J. Mc Keever and Guy M. Narbonne

With contributions by Ulrika Åberg, Lovísa Ásbjörnsdóttir, José Brilha, Tom Casadevall, Tove Damholt, Piotr Migoń, S. Felix Toteu, Paul Williams and Kyung Sik Woo



INTERNATIONAL UNION FOR CONSERVATION OF NATURE

United Nations Educational, Scientific and Cultural Organization

World Heritage Convention

문화재청
Cultural Heritage Administration

About IUCN
IUCN is a membership Union uniquely composed of both government and civil society organisations. It provides public, private and non-governmental organisations with the knowledge and tools that enable human progress, economic development and nature conservation to take place together.

Created in 1948, IUCN is now the world's largest and most diverse environmental network, harnessing the knowledge, resources and reach of more than 1,400 Member organisations and some 18,000 experts. It is a leading provider of conservation data, assessments and analysis. Its broad membership enables IUCN to fill the role of incubator and trusted repository of best practices, tools and international standards.

IUCN provides a neutral space in which diverse stakeholders including governments, NGOs, scientists, businesses, local communities, indigenous peoples organisations and others can work together to forge and implement solutions to environmental challenges and achieve sustainable development.

Working with many partners and supporters, IUCN implements a large and diverse portfolio of conservation projects worldwide. Combining the latest science with the traditional knowledge of local communities, these projects work to reverse habitat loss, restore ecosystems and improve people's well-being.

www.iucn.org
https://twitter.com/IUCN/

Geological World Heritage

A revised global framework for the application of criterion (viii) of the World Heritage Convention

Patrick J. Mc Keever and Guy M. Narbonne

With contributions by Ulrika Åberg, Lovísa Ásbjörnsdóttir, José Brilha, Tom Casadevall, Tove Damholt, Piotr Migoń, S. Felix Toteu, Paul Williams and Kyung Sik Woo

IUCN is pleased to acknowledge the support of its Framework Partners who provide core funding: Ministry of Foreign Affairs of Denmark; Ministry for Foreign Affairs of Finland; Government of France and the French Development Agency (AFD); the Ministry of Environment, Republic of Korea; the Norwegian Agency for Development Cooperation (Norad); the Swedish International Development Cooperation Agency (Sida); the Swiss Agency for Development and Cooperation (SDC) and the United States Department of State.

This publication has been made possible in part by funding from the Cultural Heritage Administration, Republic of Korea.

Published by: IUCN, Gland, Switzerland

Produced by: IUCN World Heritage Programme

Recommended citation: Mc Keever, P.J. and 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.

ISBN: 978-2-8317-2141-5 (PDF)

DOI: https://doi.org/10.2305/IUCN.CH.2021.12.en

Cover photo: Los Glaciares National Park (Argentina) © Philipp Schinz

Layout by: Guilder Design, Dublin, Ireland (www.guilderdesign.com)

Contents

Executive summary

In 2005, IUCN published a report entitled *Geological World Heritage: A Global Framework* (Dingwall et al., 2005) https://portals.iucn.org/library/node/12797. The aim of that report was to discuss and advise on the role of the World Heritage Convention in recognising and protecting geological and geomorphological heritage. By using a thematic approach, the 2005 report aimed to:

- assist States Parties in undertaking global comparative analyses of properties prior to and as part of new nominations under criterion (viii);
- assist the World Heritage Committee and its advisors to identify possible gaps in coverage of the World Heritage List;
- assist the World Heritage Committee and its advisors in their evaluation of new nominations of properties under criterion (viii) (*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 feature).*

The report identified 13 themes and, since its publication, an additional 22 geological and geomorphological properties have been inscribed on the World Heritage List under criterion (viii).

Furthermore, in 2015, UNESCO adopted the new International Geoscience and Geoparks Programme (IGGP), which recognises a new site-level designation, the UNESCO Global Geopark, which are territories of internationally significant geological heritage. As of June 2021, there are 169 UNESCO Global Geoparks in 44 countries.

Since 2005 several of the themes identified in *Geological World Heritage: A Global Framework* have been subject to substantial individual studies. The UNESCO World Heritage Committee in both 2013 and 2014 requested IUCN to revise its thematic study on geological sites, to refine the proposed 13 themes, articulate the threshold of Outstanding Universal Value and clarify the difference between the criterion (viii) of the World Heritage selection criteria and Geoparks status (noting that at that time Geoparks were not a UNESCO designation).

Accordingly, the aim of the present study is to fully revise and update the 2005 report and to look at the potential impact of the new UNESCO Global Geopark designation on future inscriptions to the World Heritage List under criterion (viii). Central to this task is a discussion on the concept of Outstanding Universal Value, and reiteration that not all sites of significance can be included on the World Heritage List. This aim of the report has been achieved through a thorough review of the 2005 report, and in particular the thematic approach to geology that the report used. This review has led to the proposal of a rationalised set of 11 themes to guide the application of criterion (viii). For each of the 11 themes, this report analyses what each theme covers, what was listed as World Heritage by 2005 and since 2005, whether the advice available at the present is sufficient for each theme, how well each theme is now represented on the World Heritage list, including geographical representation and finally tries to identify if there are any key issues that this study has uncovered. This report also examines the processes of comparative analysis and questions of site integrity in relation to properties listed for geological and geomorphological values.

Finally, this report looks in detail at the differences and similarities between geological World Heritage Properties recognised under criterion (viii) and UNESCO Global Geoparks. It examines each designation and presents a pathway to help States Parties / Member States to determine whether one of these two UNESCO designations might be appropriate for any possible new territories, and in particular to distinguish sites with the potential for inscription on the World Heritage List.

List of acronyms

GGN	Global Geoparks Network
IGCP	International Geoscience Programme
IGGP	International Geoscience and Geoparks Programme
IUCN	International Union for Conservation of Nature
OUV	Outstanding Universal Value
UGGp	UNESCO Global Geopark
UNESCO	United Nations Educational, Scientific and Cultural Organization

Acknowledgements

The authors would like to thank Tim Badman, Peter Shadie, Kristof Vandenberghe, Guy Martini and Marie-Luise Frey for their valuable comments and advice. The inputs from the independent peer reviewers of the whole text, Jonathan Larwood and Gabi Schneider, are much appreciated. Thanks are also due to Niall O'Laoghaire of Guilder Design for design and layout, and to Ulrika Åberg, Sarina van der Ploeg, Célia Zwahlen and staff of the IUCN World Heritage Programme for their support in the production process. This publication could not have been possible without the generous financial support of the Cultural Heritage Administration of the Republic of Korea. Guy Narbonne is grateful for support through a Queen's University Research Chair. IUCN thanks the study authors, as well as all the chapter authors and reviewers named above for their extensive work to contribute to producing this study. The contributions of the photographers and illustrators is also acknowledged with thanks.

Keywords

World Heritage; UNESCO Global Geoparks; Criterion (viii); Outstanding Universal Value; Global comparative analysis; History of planet Earth and the evolution of life; Tectonic systems; Erosional systems; Volcanic systems; River, lake and delta systems; Cave and karst systems; Coastal systems; Marine systems; Glacial and periglacial systems; Desert and semi-desert systems; Meteorite impacts

Introduction

Figure 1: The Giant's Causeway and Causeway Coast World Heritage Property (United Kingdom of Great Britain and Northern Ireland). The Giant's Causeway lies at the foot of basalt cliffs along the sea coast on the edge of the Antrim plateau in Northern Ireland. It is made up of some 40,000 massive black basalt columns sticking out of the sea. The dramatic sight has inspired legends of giants striding over the sea to Scotland. Geological studies of these formations over the last 300 years have greatly contributed to the development of the Earth sciences and show that this striking landscape was caused by volcanic activity during the Palaeogene, some 50–60 million years ago. © Tourism Northern Ireland

In 2005, IUCN published a report entitled, *Geological World Heritage: A Global Framework*, (Dingwall et al., 2005) and hereinafter referred to as 'the 2005 report'. The aim of that report was to discuss and advise on the role of the World Heritage Convention (hereinafter referred to as 'the Convention') in recognising and protecting geological and geomorphological heritage. By using a thematic approach, the 2005 report aimed to:

- assist States Parties in undertaking global comparative analyses of properties prior to and as part of new nominations under criterion (viii);
- assist the World Heritage Committee and its advisors to identify possible gaps in coverage of the World Heritage List;
- assist the World Heritage Committee and its advisors in their evaluation of new nominations of properties under criterion (viii) (*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 feature).*

Since the publication of the 2005 report, an additional 22 properties have been inscribed on the World Heritage List, using criterion (viii), which is used to recognise geological and geomorphological properties under the Convention. This brings the total number of geological World Heritage Properties (December 2020) to 93. Furthermore, in 2015, UNESCO adopted the new International Geoscience and Geoparks Programme (IGGP), which recognises a new site-level designation, the UNESCO Global Geopark, which are territories of internationally significant geological heritage. As of June 2021, there are 169 UNESCO Global Geoparks in 44 countries. Additionally, since 2005 several of the themes identified in the 2005 report have been subject to substantial individual studies.

The UNESCO World Heritage Committee in both 2013 and 2014 requested IUCN to revise its 2005 thematic study on geological sites, the *Geological World Heritage: A Global Framework*, to refine the proposed 13 themes, articulate the threshold of Outstanding Universal Value and clarify the

difference between the criterion (viii) of the World Heritage and Geoparks. However, at that time Geoparks were not designated by UNESCO. That changed in 2015 when UNESCO adopted the new designation of UNESCO Global Geopark and all pre-existing Global Geoparks became UNESCO Global Geoparks.

Accordingly, the aim of the present study is to fully revise and update the 2005 report and to look at the potential impact of the new UNESCO Global Geopark designation on future inscriptions to the World Heritage List under criterion (viii). Central to this is a discussion on the concept of Outstanding Universal Value and a reiteration that not all sites of significance can make it onto the World Heritage List. This has been followed by a thorough review of the 2005 report, in particular the thematic approach to geology that the report used. The report identified 13 themes. The review has reduced this number to 11 themes, some of them are the same as in the 2005 reports, there is one new theme and some of the 2005 themes have been re-named and/or combined.

Finally, with the approval of the UNESCO Global Geopark designation, this study provides a framework for assessing which designation, World Heritage or UNESCO Global Geopark, might be appropriate when considering geological and geomorphological sites for international recognition.

However, as stated, before outlining the revised thematic study, it is essential to examine closely the idea of Outstanding Universal Value, which is the core concept behind any inscription to the World Heritage List.

Outstanding Universal Value

According to the latest version of the *Operational Guidelines for the Implementation of the World Heritage Convention* published by the UNESCO World Heritage Centre in 2019:

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

But what exactly is 'Outstanding Universal Value', or OUV, and how can it be defined in the context of geological heritage? A series of criteria and conditions have been developed to evaluate OUV. Six criteria (i – vi) cover cultural properties while criteria (vii) – (x) cover natural properties (see below). Of course, a nomination can include both cultural and natural criteria. The guidelines also state that for a property to be deemed of OUV it must also meet the conditions of integrity and/or authenticity and must have an adequate protection and management system to ensure its safeguarding. It is therefore clear from the Operational Guidelines (UNESCO World Heritage Centre, 2019) that OUV is a three-pronged statement where a World Heritage Property must fulfil one or more criteria (criterion (viii) for geological properties), it must fulfil the conditions of integrity and it must be adequately protected and managed. The full ten criteria are:

Criterion (i) *- to represent a masterpiece of human creative genius*

Criterion (ii) *- to exhibit an important interchange of human values, over a span of time or within a cultural area of the world, on developments in architecture or technology, monumental arts, town-planning or landscape design*

Criterion (iii) *- to bear a unique or at least exceptional testimony to a cultural tradition or to a civilization which is living or which has disappeared*

Criterion (iv) *- to be an outstanding example of a type of building, architectural or technological ensemble or landscape which illustrates (a) significant stage(s) in human history*

Criterion (v) *- to be an outstanding example of a traditional human settlement, land-use, or sea-use which is representative of a culture (or cultures), or human interaction with the environment especially when it has become vulnerable under the impact of irreversible change*

Criterion (vi) *- to be directly or tangibly associated with events or living traditions, with ideas, or with beliefs, with artistic and literary works of outstanding universal significance. (The World Heritage Committee considers that this criterion should preferably be used in conjunction with other criteria)*

Criterion (vii) *- to contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance*

Criterion (viii) *- 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*

Criterion (ix) *- to be outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals*

Criterion (x) *- to contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation*

Fulfilling Criterion (viii): a revised thematic approach

A key phrase from the Operational Guidelines (UNESCO World Heritage Centre, 2019) states that, "[t]he Convention is not intended to ensure the protection of all properties of great interest, importance or value, but only for a select list of the most outstanding of these from an international viewpoint." Furthermore, "[i]t is not to be assumed that a property of national and/or regional importance will automatically be

inscribed on the World Heritage List." This is the first key point to bear in mind. Just because a site may be of regional or national significance, it does not mean that it is of OUV. The site must be absolutely exceptional at the global level in what it contains or displays, and among the priceless and irreplaceable assets of humanity as a whole.

The most fundamental part of the nomination process is clarifying if a property could be considered to have OUV. Until potential OUV and the attributes conveying this value has been defined, it is not possible to develop other essential aspects of the nomination including the comparative analysis, the definition of boundaries and the protection and management, which should reflect the extent and character of the attributes that convey the value.

The 2005 report identified 13 themes to assist in determining whether a World Heritage Property fulfils the terms of criterion (viii). Based on consideration of the effectiveness of the implementation of these themes, and based on review by the study and chapter authors, this report has reorganised the approach to geological World Heritage in relation to a reorganised list of 11 themes. The study has also reviewed and classified all existing geological World Heritage Properties, considering their OUV in relation to these 11 themes (Annex 1). Many properties contain features relevant to more than one theme, but for brevity the list of 'ancillary themes' in Annex 1 only includes significant contributions that warranted mention in the Statement of OUV published on the World Heritage website. Furthermore, it was apparent that the OUV of five properties cover two primary themes. Therefore, the 93 World Heritage Properties inscribed under criterion (viii) are listed 98 times under the 11 primary themes. In all of these themes, States Parties must ask themselves if their proposed site really does display or contain something so internationally exceptional that is of true global significance.

The 11 themes identified in this report are:

Theme 1: History of planet Earth and the evolution of life

Theme 1 documents major events in Earth history and the fossil record of life. It combines two related themes from the 2005 report: Theme 4 'Stratigraphic Properties – Rock sequences that provide a record of key Earth history events' and Theme 5 'Fossil Properties – The record of life on Earth represented in the fossil record'.

Theme 2: Tectonic systems

The Tectonic systems theme includes the 'Tectonic and structural features' and the 'Mountain systems' themes as defined in the 2005 report. This merger was justified by the fact that tectonics is the process that governs the movement of Earth's tectonic plates at their boundaries as well as heat, energy and material transfer from the Earth's interior towards the surface and vice-versa: seafloor spreading coupled with subduction, rifting, mountain building, volcanoes, faults, earthquakes, erosion, etc., are direct or indirect expressions of tectonic processes. However, with a view of providing a meaningful representation to the general public, we have restricted the scope of the 'Tectonic systems' theme to mountain ranges, convergent plate boundaries (subduction zones), divergent plate boundaries (ocean ridges), sliding plate boundaries (transform zones), continental rifting valleys and cratonic shields, while keeping 'Volcanic systems' and 'Erosional systems' as separate themes.

Theme 3: Erosional systems

The theme 'Erosional systems' was not explicitly present in the 2005 report. One might argue that it is the equivalent of the 'Mountain systems' with partial overlap with the 'Arid and semi-arid desert systems', but there were already a number of World Heritage Properties inscribed under criterion (viii) which were neither mountains nor located in drylands but were erosional in nature. Additionally, a significant number of properties were inscribed in recognition of their scenic beauty (criterion (vii)), although their justifications clearly highlighted geomorphological features and processes more in line with criterion (viii). The relevance of 'Erosional systems' for criterion (viii) is twofold. First, erosional systems show "significant on-going geological [in fact, geomorphological] processes in the development of landforms" and secondly, these processes may produce "significant geomorphological or physiographical features."

Theme 4: Volcanic systems

Volcanoes are true wonders of the planet; they are central to the formation, evolution and sustenance of biological systems; they form some of our deepest and most significant cultural attachments to the land; and they attract large numbers of visitors for their aesthetic appeal. The theme Volcanic systems was originally included in the 2005 report as Theme 2. Furthermore, volcanic systems were the subject of the 2009 volcano thematic study by Wood (2009). In 2019, IUCN published an updated report on *World Heritage Volcanoes* (Casadevall et al., 2019), which we draw on here for this discussion.

Theme 5: River, lake and delta systems

The theme covers fluvial, lacustrine and deltaic landscapes and their associated features. These are systems resulting from large-scale fluvial processes, which have formed and influenced the development of valleys, flood plains, river corridors, wetlands, lakes and deltas, along with instream features and morphology (Ferrier & Jenkins, 2010). Spectacular features such as waterfalls are also included under this theme. The theme includes foremost alluvial landscapes and depositional features, while erosional features, such as river canyons, are covered primarily by Theme 3. In terms of deltas, this theme only covers the special cases of inland and inverted deltas, while coastal deltas are covered within Theme 7. There is also some overlap with Theme 9, as many important fluvial, lacustrine and deltaic processes and landforms occur in glacial landscapes. The River, lake and delta systems theme is equivalent to the 'Fluvial, lacustrine and deltaic systems' theme from the 2005 report. The main driving process for the formation of all inland waters is the hydrological cycle. Water evaporates from the oceans and precipitates over the continents, where it flows back to the sea along rivers and streams, reworking large amounts of sediments and forming some of our most familiar fluvial landforms. Some of the water resides in wetlands or lakes for many years, or in ice caps for

Figure 2: Flow chart summarising the process that should be undertaken when assessing if a site or place demonstrates OUV.

thousands or millions of years (Moss, 2010).

Theme 6: Cave and karst systems

The theme covers systems developed predominantly by the process of dissolution of soluble rocks. This mainly involves carbonate rocks (limestone, dolomite, marble) and evaporite rocks (gypsum, salt). In these terrains drainage disappears in enclosed depressions, rivers sink underground, and caves are signature landforms. Some sandstone landscapes are also included because these rocks can become relatively soluble under subtropical and tropical conditions. Natural processes involved in the development of Caves and karst systems are explained by Ford & Williams (2007, 2011) and Palmer (2007).

Theme 7: Coastal systems

Coastal systems refer to physical processes and physiographical features present in the coastal zone. The coastal zone is the boundary between land and sea, a highly dynamic interface between geological and oceanographical features and including atmospheric (weather and climate) processes and how these are affected by land and sea (Abdulla et al., 2013). But the interface - the shoreline - is mobile, because land can be uplifted or subside, and sea level can rise or fall. Hence coastal landscapes, landforms and sediments develop along a moving interface between land and sea, as well as over long periods of time. The zone over which this interaction plays out can be kilometres wide, and so landforms produced by coastal processes can be found well inland, well above sea level, kilometres offshore and well below present sea level. In many places, coastal landforms are also influenced by ancient antecedent topography.

Theme 8: Marine systems

Marine systems includes seafloor and submarine features, coral islands, reefs and oceanic islands. The theme encompasses "significant on-going geological processes in the development of landforms, or significant geomorphological features" found in the shallow and deep marine areas. This theme comprises the former Theme 9 of the 2005 report: 'Reefs, atolls and oceanic islands', but additionally includes the wide range of ongoing processes and geological features of marine areas including physical, chemical and biological processes, tectonic settings and sedimentary environments including continental shelf and slope, basin floors, abyssal plains, oceanic trenches, submarine ridges.

Marine areas cover 70% of the Earth surface, most of which is in deep marine areas. In recent years there have been a number of advances in the study of the submarine environment including extensive mapping of the seafloor, which has produced a plethora of new information on the marine systems in the deep marine areas.

Theme 9: Glacial and periglacial systems

This theme includes geological processes, landscape and geomorphological features developed by past or present glacial and periglacial systems. Theme 9 is equivalent to the former two themes, 10 'Glaciers and ice caps' and 11 'Ice Ages', described in the 2005 report. The new theme, Theme 9, includes 17% of the World Heritage Properties inscribed under criterion (viii) for their OUV (primary elements).

Theme 10: Desert and semi-desert systems

The theme 'Desert and semi-desert systems', present in the 2005 report as 'Arid and semi-arid desert systems', emphasises specific environments rather than a particular surface process or group of processes. However, in order to minimise overlaps within the present framework and to make it as clear as possible, this category is understood as primarily designed to cover aeolian processes and landforms, as well as features produced by intermittent runoff and evaporation. Thus, it includes landscape features such as dunes and dune fields of various types and sizes, yardangs, deflation hollows, wadis and playas.

Theme 11: Meteorite impacts

The theme of Meteorite impacts includes features produced by the impacts of meteors, comets, asteroids and other extra-terrestrial objects with the Earth, including both physical structures formed by extra-terrestrial impacts, such as impact craters, as well as major effects caused by them, such as mass extinction. Impacts by, and accretion of, extra-terrestrial bodies was the fundamental process by which the Earth grew to its current size. It was also a dominant geological process throughout the early history of the Solar System and a variety of possible effects have been ascribed to impacts on Earth including the origin of the Earth's moon, the contribution to the Earth's quantity of volatile gases, and effects on the evolution of early life. In more recent geological time, at least one mass extinction event is linked to global effects caused by a major impact event (e.g. Osinski & Pierazzo, 2012).

Identifying potential Outstanding Universal Value

Considering that uniqueness does not automatically equate with OUV, the essential first step is thus to identify any value(s) of a site fulfilling criterion (viii) and thus with the potential to justify OUV of the proposed property. For this process, it is important to set out all geological values of the site

and evaluate these based on the 11 themes presented in this report, in order to clarify if and how these values could potentially address one or more gaps on the World Heritage List. Subsequently a definition of the values proposed to fulfil the criterion and a description of the attributes that convey this value, should be set out in a relatively short text. This will then form the basis for undertaking a rigorous global comparative analysis and, in the event that this demonstrates a strong case for OUV, will be the basis for a proposed Statement of OUV to be included in the nomination of the property (Figure 2).

To nominate a site to the World Heritage List, it must first have been included on a State Party's Tentative List. Tentative List are lists of sites that the States Parties consider to be of OUV and that they therefore consider suitable for inscription on the World Heritage List.

Thematic study

Before continuing with a discussion of the comparative analysis process, the following section will look closely at the 11 themes identified for this report. As in the 2005 report, the 11 themes provide a basis upon which nominated candidate World Heritage Properties (using criterion (viii)) can be assessed regarding their OUV from the viewpoint of science and conservation. It is also intended that the 11 themes will guide national and regional advisors to assess the relative importance of sites and for IUCN to assess nominations and offer advice to interested parties.

In particular, in revising the themes, specific questions were asked:

What does the theme cover?

What had been listed as World Heritage by 2005?

What has been listed as World Heritage since 2005?

Is the thematic advice we have at present sufficient for this theme?

How well is the theme now represented on the World Heritage List, including its geographical distribution?

Any key issues (things to avoid, lessons learned, considerations like serial properties, relevance to other criteria, any 'big stories' missing, key properties for this theme that would meet criterion (viii) that are listed under other criteria, interplay with biodiversity, culture)?

Theme 1:
History of planet Earth and the evolution of life

Guy M. Narbonne and Patrick J. Mc Keever

Figure 3: Monte San Giorgio (Italy & Switzerland) is regarded as the best fossil record of marine life from the Triassic Period (245–230 million years ago). Source: Woudloper/ Wikimedia Commons

What does the theme cover?

Theme 1 documents major events in Earth history and the fossil record of life. It combines two related themes from the 2005 report: Theme 4 'Stratigraphic Properties – Rock sequences that provide a record of key Earth history events' and Theme 5 'Fossil Properties – The record of life on Earth represented in the fossil record'.

Theme 1 is the sole theme for 18 World Heritage Properties and is an important ancillary element of the OUV for six additional properties (Table 1; Annex 1). Fossils are abundant and important in several other World Heritage Properties inscribed under criterion (viii) such as Gros Morne National Park (Canada) and Yellowstone National Park (United States of America), but are less significant than other features that define the OUV in these properties.

The over-riding message from the combined properties representing Theme 1 is the co-evolution of the Earth and life – the recognition that the major tectonic, oceanographic, atmospheric, cryogenic and astronomical events and processes that have affected our planet over geological timescales have also profoundly influenced the evolution and ecology of life on Earth, and that some major events in biological evolution have profoundly changed the Earth's surface and atmosphere. Theme 1 World Heritage Properties include the conditions for early life on the primitive Earth more than three billion years ago (Barberton Makhonjwa Mountains (South Africa)), the oldest large and complex multicellular life (Mistaken Point (Canada)), the development of marine animal life in the Cambrian explosion (Burgess Shale in Canadian Rocky Mountain Parks (Canada), Chengjiang Fossil Site (China)), the Devonian and Carboniferous 'terrestrial revolution' of land plants that dramatically increased atmospheric oxygen and led to the proliferation of life on land and in freshwater rivers and lakes (Miguasha National Park, Joggins Fossil Cliffs both in Canada), and abundant evidence of climatic control on the Cenozoic evolution of mammals (Australian Fossil Mammal Sites (Riversleigh / Naracoorte), (Australia)), and early hominids (Lake Turkana National Parks (Kenya)).

Properties in Theme 1 contain an outstanding record of the diversity of fossil life. In addition to the shells and bones that characterise Phanerozoic fossil assemblages worldwide, several properties (Burgess Shale in Canadian Rocky Mountain Parks, Chengjiang Fossil Site, Messel Pit Fossil Site, Mistaken

Table 1: World Heritage Properties inscribed under criterion (viii) with Theme 1 as the major theme for inscription, or as an ancillary theme.

Criterion (viii) Properties Inscribed Principally Under Theme 1	Date Inscribed (extension)	Criterion (viii) Properties for which Theme 1 was an Ancillary Theme for Inscription	Date inscribed (extension)
Dinosaur Provincial Park, Canada	1979	Grand Canyon National Park, United States of America	1979
Great Smoky Mountains National Park, United States of America	1983	Ngorongoro Conservation Area, United Republic of Tanzania	1979 (2010)
Vallée de Mai Nature Reserve, Seychelles	1983	Willandra Lakes Region, Australia	1981
Canadian Rocky Mountain Parks, Canada	1984 (1990)	Tasmanian Wilderness, Australia	1982 (1989)
Wet Tropics of Queensland, Australia	1988	Gondwana Rainforests of Australia, Australia	1986 (1994)
Shark Bay, Western Australia, Australia	1991	Te Wahipounamu – South West New Zealand, New Zealand	1990
Australian Fossil Mammal Sites (Riversleigh / Naracoorte), Australia	1994	The Dolomites, Italy	2009
Messel Pit Fossil Site, Germany	1995	Stevns Klint, Denmark	2014
Lake Turkana National Parks, Kenya	1997 (2001)		
Miguasha National Park, Canada	1999		
Ischigualasto / Talampaya Natural Parks, Argentina	2000		
Dorset and East Devon Coast, United Kingdom of Great Britain and Northern Ireland	2001		
Monte San Giorgio, Italy and Switzerland	2003 (2010)		
Wadi Al-Hitan (Whale Valley), Egypt	2005		
Joggins Fossil Cliffs, Canada	2008		
Chengjiang Fossil Site, China	2012		
Mistaken Point, Canada	2016		
Barberton Makhonjwa Mountains, South Africa	2018		

Point) are famous as Fossil Lagerstätten in which soft tissues were exquisitely preserved. Fossil plants and terrestrial arthropods such as insects are abundant in most properties at least partly deposited in freshwater or terrestrial settings (Australian Fossil Mammal Sites (Riversleigh / Naracoorte), Dinosaur Provincial Park, Dorset and East Devon Coast, Ischigualasto / Talampaya Natural Parks, Joggins Fossil Cliffs, Messel Pit Fossil Site, Miguasha National Park) and even in some properties originating in marginal or fully marine settings (Monte San Giorgio, Wadi Al-Hitan (Whale Valley)). Trace fossils, the fossilised tracks, trails and burrows of mobile animals, are present in most Theme 1 properties and provide evidence of animal behaviour thousands to hundreds of millions of years ago. Microfossils are preserved in nearly all Theme 1 fossil sites, including Barberton Makhonjwa Mountains, which dates back 3.6 to 3.25 billion years ago shortly after the origin of microscopic life on our planet.

Most of the properties that achieved World Heritage recognition prior to 1995 were inscribed in combination with other natural or cultural OUV criteria, commonly (iii), (vii), (ix), or (x). Since 1995, most properties in Theme 1 have been inscribed solely under criterion (viii).

What had been listed as World Heritage by 2005?

At the time of the publication of the 2005 report, 14 properties had been inscribed onto the World Heritage List under criterion (viii) and under the former Themes 4 (Stratigraphic Properties) and 5 (Fossil Properties). They included, for example, Dinosaur Provincial Park (Canada), Shark Bay, Western Australia (Australia), Messel Pit Fossil Site (Germany) and the Dorset and East Devon Coast (United Kingdom of Great Britain and Northern Ireland) (Table 1; Annex 1).

What has been listed as World Heritage since 2005?

Since 2005 an additional four properties have been inscribed onto the World Heritage List, which either totally or partially fall under this new Theme 1 and the former Themes 4 and 5. The new properties are Joggins Fossil Cliffs (Canada), Chengjiang Fossil Site (China), Mistaken Point (Canada) and Barberton Makhonjwa Mountains (South Africa).

Is the thematic advice we have at present sufficient for this theme?

Publication of an IUCN-commissioned report *Earth's geological history: A contextual framework for assessment of World*

Figure 4: Messel Pit Fossil Site (Germany) is the richest site in the world for understanding the living environment of the Eocene, between 57 million and 36 million years ago. © Limes.Media, Tim Schnarr. Source: UNESCO

Heritage fossil site nominations (Wells, 1996) provided a key framework for this analysis. Wells' recommendations, slightly modified and printed in UNESCO World Heritage Centre (2011, p. 42 and Annex 3 of this report), shaped all subsequent nominations and decisions in Theme 1 and have been emulated by other themes. Wells' proposed separation between pre-Cambrian and Phanerozoic properties (Recommendation 4) has become somewhat blurred since 2005, with most recently inscribed Theme 1 properties emphasising OUV as both a landmark in biological evolution and as an important step in the evolution of the Earth system, and his recommendations 5 and 9 about the need to constitute expert panels "to select properties worthy of evaluation for Heritage listing" were not implemented. All recent nominations in Theme 1 have used a similar 'best practice' method for the comparative analysis of fossil properties (IUCN, 2016, p. 56-57; Thomas and Narbonne, 2015, p. 59-69). In summary, the thematic guidance for this theme is good but requires regular attention to ensure it remains relevant and effective.

How well is the theme now represented on the World Heritage List, including its geographical distribution?

World Heritage Properties representing Theme 1 are present on every inhabited continent. There is excellent temporal coverage of the Phanerozoic, the eon of Earth history characterised by abundant visible fossils, with seventeen World Heritage fossil properties (Table 1; Figure 5; Annex 1). Many geological periods host a site; the Cambrian and Triassic each contain multiple properties that reflect different biotopes (e.g. terrestrial versus marine) and preservational modes (e.g. Lagerstätten versus mainly skeletal remains) during that time. The most significant remaining gaps are at the interface between palaeontology and global change over geological timescales, especially the mass extinction events that were a primary control on global diversity throughout the Phanerozoic (Raup & Sepkoski, 1982; Fan et al., 2020). The terminal Cretaceous extinction that exterminated 50% of animal species including dinosaurs is superbly reflected in the fossil record at Stevns Klint (Denmark), but the equally profound Palaeozoic extinctions at the end of the Ordovician, Devonian and Permian are not yet represented in any World Heritage Property. Other Phanerozoic intervals of extreme global change and extinction (e.g. Mesozoic Ocean Anoxic Events, Palaeocene – Eocene Thermal Maximum event) could also be considered. Cenozoic (mainly Pleistocene and modern) glaciation processes and products are well covered in Theme 9, but ancient glacial events in deep time (e.g. the Carboniferous-Permian Gondwana glaciations and the Neoproterozoic and Paleoproterozoic 'Snowball' glaciations) profoundly affected the evolution of life and could usefully be described in Theme 1. Ichnology, where animal track properties can yield behavioural information that cannot be preserved in shells and bones, is represented, for example, in the hominid tracksite at Laetoli in Ngorongoro Conservation Area (United Republic of Tanzania). A number of previous World Heritage nominations based solely on dinosaur footprints have been deemed inadequate to show OUV. However, a coherent transnational nomination of exceptional sites demonstrating a compelling reason for global significance and OUV, might be considered.

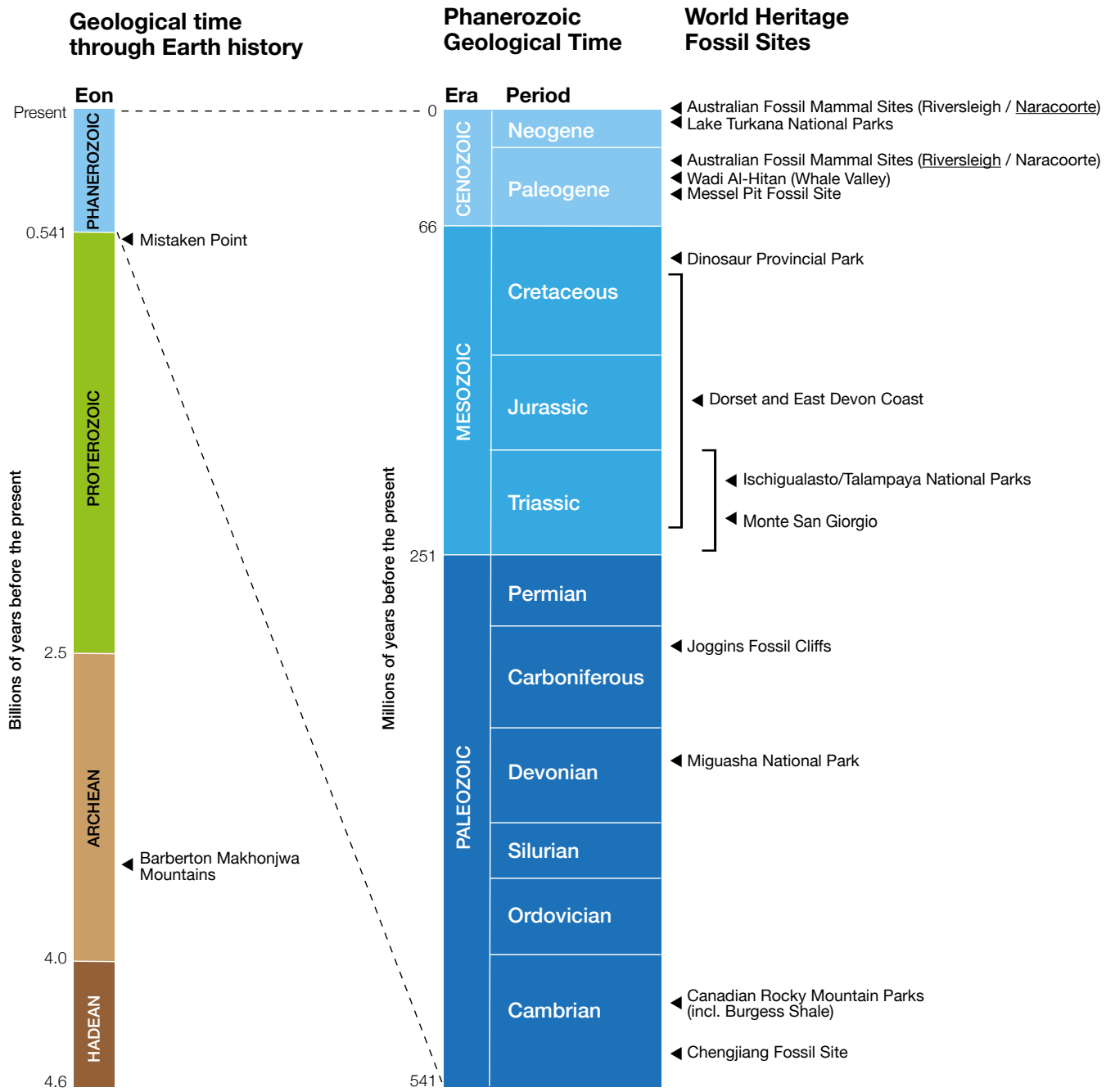


Figure 5: Temporal distribution of UNESCO Fossil Properties (Theme 1). Modified from Thomas and Narbonne, 2015, Fig. 3.4. Formal stratigraphic names and dates are from the International Chronostratigraphic Chart (May 2021)[1]

In contrast with the abundance of World Heritage fossil properties in Phanerozoic strata, the Hadean, Archean and Proterozoic eons that collectively comprise the first four billion years of Earth evolution (85% of Earth history) contain only two recently inscribed UNESCO World Heritage Properties located at nearly opposite ends of the pre-Cambrian timescale (Figure 5 left hand column; Annex 1). Additional major events in pre-Cambrian evolution not included in any World Heritage fossil property include: the earliest diverse signs of life 3.5 billion years ago; the Great Oxidation Event (2.4 to 1.8 billion years ago) that transformed the chemistry of the Earth's surface and made eukaryotes possible; 'Snowball Earth', the nearly total freezing of the entire Earth surface 720-635 million years ago that ultimately led to the appearance of animals; and the diverse Ediacara biota that postdated Mistaken Point life and immediately preceded the Cambrian explosion of shelly animals.

Any key issues (things to avoid, lessons learned, considerations like serial properties, relevance to other criteria, any 'big stories' missing, key properties for this theme that would meet criterion (viii) that are listed under other criteria, interplay with biodiversity, culture)?

Several Theme 1 properties inscribed between 1983–1991 used criteria that differ from modern usage. Four properties inscribed under criterion (viii) - Great Smoky Mountains National

1. https://stratigraphy.org/ICSchart/ChronostratChart2021-05.pdf

Park (United States of America), Wet Tropics of Queensland (Australia), Vallée de Mai Nature Reserve (Seychelles) and Shark Bay, Western Australia (Australia) – do not contain fossil assemblages of OUV but are regarded as providing modern living analogues for ancient biotopes and biological constructions thousands to billions of years old. This view is not presently followed, and since 1991, all criterion (viii) properties in Theme 1 have been inscribed on the basis of outstanding fossil assemblages and events in the deep-time record of life and environments. Modern sedimentary environments exemplified in properties such as the Wadden Sea (intertidal sand and mud flats), Great Barrier Reef (shallow-marine carbonate sediments including reefs), Namib Sand Sea (aeolian dunes), Nahanni National Park and Río Plátano Biosphere Reserve (rivers) form the key to interpreting process sedimentology in deep time, but are not in and of themselves major events in Earth history and the fossil record of life.

There is some overlap with criterion (iii) to "bear a unique or at least exceptional testimony to a cultural tradition or to a civilisation which is living or which has disappeared" for properties containing early hominid fossils. The hominid fossil properties Archaeological Site of Atapuerca (Spain), Sangiran Early Man Site (Indonesia) and Fossil Hominid Sites of South Africa (South Africa) are inscribed under criterion (iii), whereas hominid fossils in Ngorongoro Conservation Area (United Republic of Tanzania) and Lake Turkana National Parks (Kenya) are inscribed under criterion (viii). The hominid record at Willandra Lakes Region (Australia) is inscribed under criterion (iii) but its geology including giant marsupial fossils is inscribed under criterion (viii). This overlap between criterion (iii) and criterion (viii) in properties preserving the record of fossil hominids partly reflects the background of the nomination of these properties and also partly reflects the timescale of hominid evolution over the past seven million years.

Finally, palaeontology has a huge appeal throughout society worldwide. Fossil properties (Theme 1) provide an opportunity for the public to see outstanding fossil assemblages in the context of the inter-relationship between global change and the evolution of life over geologic timescales. Evidence of past global change can help to inform the public about potential processes, effects and magnitudes of present and future global change. This will be enhanced as States Parties nominate new sites that fill the identified gaps in global extinction events and major environmental and climatic events in the deep-time record of life on Earth.

Theme 2:
Tectonic systems

Tom Casadevall and S. Felix Toteu

Figure 6: Tajik National Park (Mountains of the Pamirs), (Tajikistan) offers a unique opportunity for the study of plate tectonics and continental subduction phenomena thereby contributing to our fundamental understanding of Earth building processes. © Kasirov K. Source: UNESCO

What does the theme cover?

The Tectonic systems theme includes the 'Tectonic and structural features' and the 'Mountain systems' themes as defined in the 2005 report. This merger was justified by the fact that tectonics is the process that governs the movement of Earth's tectonic plates at their boundaries as well as heat, energy and material transfer from the Earth's interior towards the surface and vice-versa: seafloor spreading coupled with subduction, rifting, mountain building, volcanoes, faults, earthquakes, erosion, etc., are direct or indirect expressions of tectonic processes. However, with a view of providing a meaningful representation to the general public, we have restricted the scope of the 'Tectonic systems' theme to mountain ranges, convergent plate boundaries (subduction zones), divergent plate boundaries (ocean ridges), sliding plate boundaries (transform zones), continental rifting valleys and cratonic shields, while keeping 'Volcanic systems' and 'Erosional systems' as separate themes.

What had been listed as World Heritage by 2005?

Utilising the current Themes, eight properties of the 71 properties inscribed on the World Heritage List by 2005 had gained their recognition mainly or solely under Theme 2 (Table 2; Annex 1). Several other mountain systems, such as the Sagarmatha National Park (Nepal), were recognised under criterion (vii).

What has been listed as World Heritage since 2005?

Based on the new theme proposed here, two properties were inscribed since 2005 mainly because of tectonic features while three additional properties utilise Theme 2 as an important ancillary theme in their inscription (Table 2; Annex 1).

Is the thematic advice we have at present sufficient for this theme?

There is no separate thematic study on this theme, and the scope of inscriptions shows both limited geographical balance, and that there is considerable confusion in the potential application of this theme, and confusion with other manifestations of tectonism (such as volcanoes). The two newly inscribed properties since 2005 are both associated tectonically with the Alpine orogeny in western Europe, which does not fulfil the geographical diversification requested in

Table 2: World Heritage Properties inscribed under criterion (viii) with Theme 2 as the major theme for inscription, or as an ancillary theme.

Criterion (viii) Properties Inscribed Principally Under Theme 2	Date Inscribed (extension)	Criterion (viii) Properties for which Theme 2 was an Ancillary Theme for Inscription	Date inscribed (extension)
Gondwana Rainforests of Australia, Australia	1986 (1994)	Canadian Rocky Mountain Parks, Canada	1984 (1990)
Galápagos Islands, Ecuador	1978 (2001)	Te Wahipounamu – South West New Zealand, New Zealand	1990
Gros Morne National Park, Canada	1987	Canaima National Park, Venezuela	1994
Lake Baikal, Russian Federation	1996	Swiss Alps Jungfrau-Aletsch, Switzerland	2001 (2007)
Heard and McDonald Islands, Australia	1997	Papahānaumokuākea, United States of America	2010
Macquarie Island, Australia	1997	Tajik National Park (Mountains of the Pamirs), Tajikistan	2013
Lorentz National Park, Indonesia	1999	Barberton Makhonjwa Mountains, South Africa	2018
Three Parallel Rivers of Yunnan Protected Areas, China	2003		
Swiss Tectonic Arena Sardona, Switzerland	2008		
Chaîne des Puys - Limagne fault tectonic arena, France	2018		

2005. However, the three recent properties for which Theme 2 is an ancillary theme are regionally diverse: Barberton Makhonjwa Mountains in Africa, Tajik National Park (Mountains of the Pamirs) in Central Asia and Papahānaumokuākea in the central Pacific Ocean.

How well is the theme now represented on the World Heritage List, including its geographical distribution?

In total, the geographical distribution is as follow: Europe & North America 4, Asia & Pacific 5, Latin America & Caribbean 1. Generally, there is a weak representation worldwide, and especially in Africa and the Arab States, of the tectonic theme, considering the many past and modern tectonic processes that have shaped the landscape around the world.

Any key issues (things to avoid, lessons learned, considerations like serial properties, relevance to other criteria, any 'big stories' missing, key properties for this theme that would meet criterion (viii) that are listed under other criteria, interplay with biodiversity, culture)?

Like most aspects of the geological sciences, no theme is truly separate from other themes. The 11 themes in this report are not silos. Perhaps the greatest demonstration of this is the link between tectonic systems and volcanic systems. Volcanic systems mostly appear at the boundaries of tectonic plates, where tectonic systems are also actively being formed. Of the 12 World Heritage Properties identified in Annex 1 has having been inscribed primarily for volcanic systems, all but four are intimately associated with active tectonic boundaries. Two other properties are associated with volcanic hotspots, one with recent, though no longer, active volcanism. Only one property is associated with volcanism in deeper geological time (Giant's Causeway and Causeway Coast, United Kingdom of Great Britain and Northern Ireland (Figure 1)). For the sake of this report, Theme 4 refers specifically to features associated with the extrusion of magma and the features created while Theme 2 refers to non-volcanic features associated with the interaction of tectonic plates both in the present and in the geological past.

The Plate Tectonic Map of the world (Figure 7) combined with the World Physical Map (Figure 8) reveals the potential for a more balanced distribution of tectonic features worldwide. States Parties in various regions where these prominent tectonic features appear should be encouraged to review their Tentative List to include new properties. In this regard, many countries in all regions of the world have potential for World Heritage Properties ranging from mountain range to rift valley systems properties. Countries in Asia & Pacific can enrich their inscribed properties or Tentative List with outstanding sites witnessing tectonics features at subduction zones as well as at oceanic trenches and collision zones. For example, Kermadec Islands and Marine Reserve, which is currently on the Tentative List of New Zealand under criterion (viii), was shaped by the subduction of the Pacific Plate under the Indo-Australian Plate, with the Kermadec Trench being one of Earth's deepest oceanic trenches, reaching a depth of 10,047 m. The Andean mountain chain of South America, the Trans-Mexican Volcanic Belt and the Cascade volcanic range of North America are notable examples of subduction zone tectonics and yet have no volcanic or tectonic features listed under criterion (viii) (Casadevall et al., 2019). This represents an important gap for World Heritage Properties in the Americas. Outstanding examples of ocean floor spreading are the Mid-Atlantic Ridge

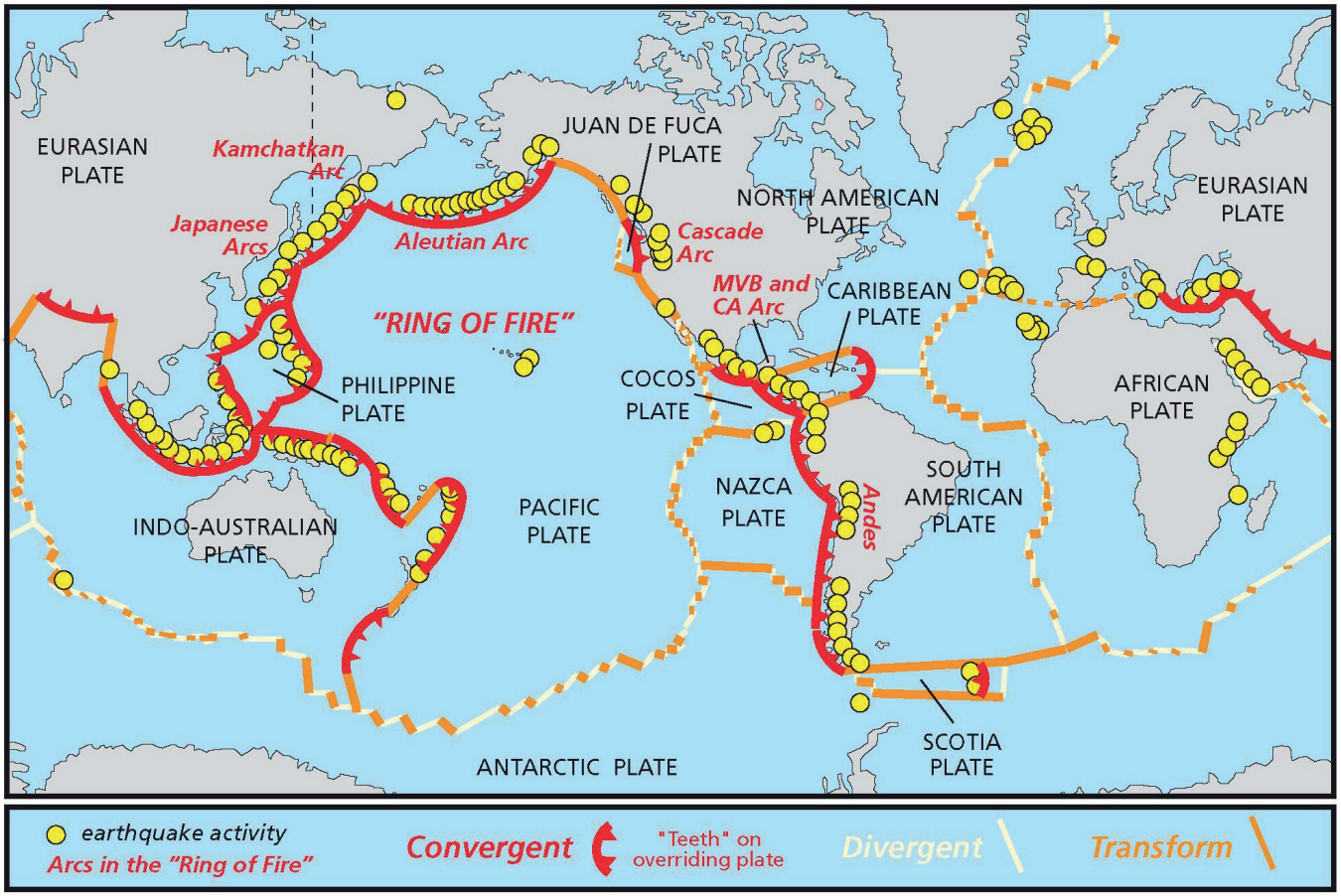


Figure 7: Plate tectonic map of the World. © United States National Park Service

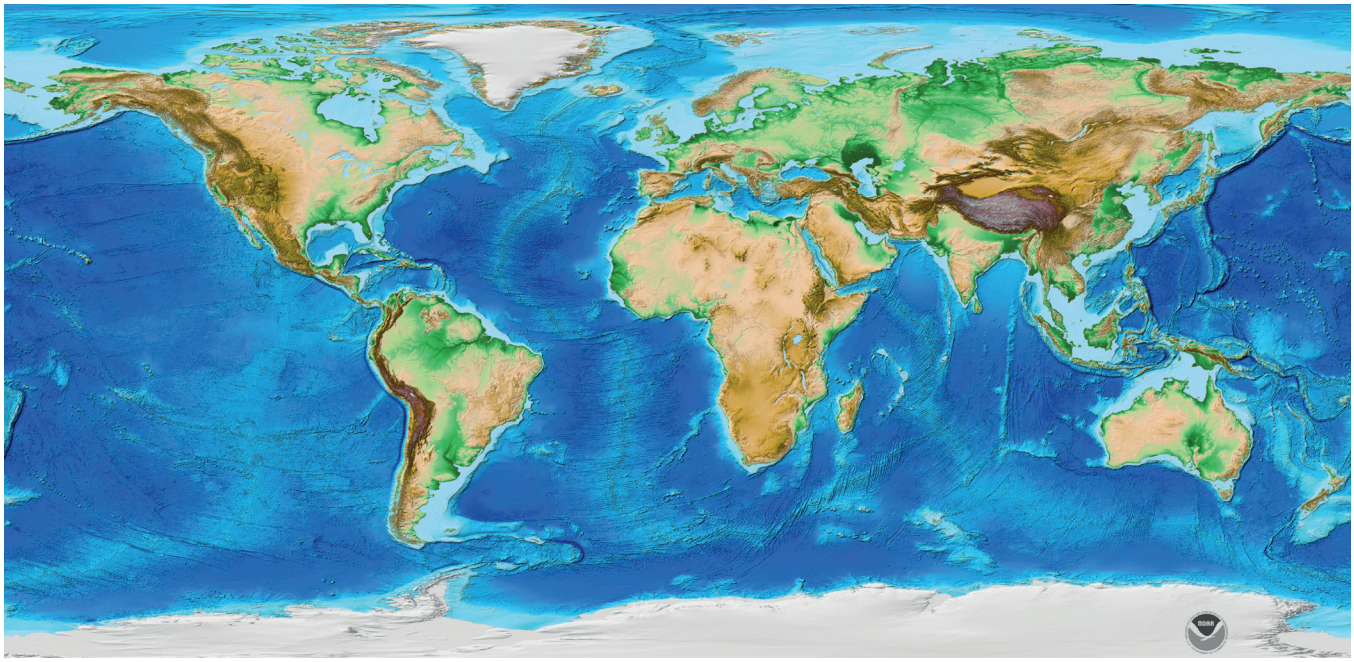


Figure 8: World Physical Map. © National Centers for Environmental Information, National Oceanic and Atmospheric Administration (NOAA)

Figure 9: Lorentz National Park (Indonesia). The geology and landforms of Lorentz National Park display graphic evidence of Earths' history. Located at the meeting point of two colliding continental plates, the area has a complex geology with ongoing mountain formation as well as major sculpting by glaciation and shoreline accretion. The dominating mountain range is a direct product of the collision between the Australian and Pacific tectonic plates. © Raiyani Muharramah. Source: Shutterstock.com

and East Pacific Rise that have produced extensive valley systems. Portugal has already considered a portion of the Mid-Atlantic Ridge that includes the Azores in its Tentative List in 2017. Indeed, there are very few countries that can add more about tectonic features telling the history of ocean floor spreading, the exceptions being Iceland, which lies on the mid-Atlantic Ridge and the countries around the Red Sea.

On the continents, the East African Rift Valley and the Baikal Rift Zone are Earth's two prominent continental rift valley systems. The two branches of the East African Rift are relayed to the north through the Afar Triangle to the Red Sea Rift and the Gulf of Aden. Each of these rift systems is unique, each telling in its own way the story of the early stage of continental break and drift. However, none of them host World Heritage inscribed under criterion (viii) for tectonic features, although they host other properties inscribed under other criteria. Examples are Lake Baikal (Russian Federation) inscribed in 1996 under criteria (vii), (viii), (ix) and (x), Kilimanjaro National Park (United Republic of Tanzania), Mount Kenya National Park /Natural Forest (Kenya) and Lake Malawi National Park (Malawi) inscribed under criteria (vii), (ix) and/or (x) or Virunga National Park (Democratic Republic of the Congo), Lake Turkana National Parks (Kenya) both inscribed under criteria (vii), (viii) (ix) and/or (x).

The Cameroon Line, running from Atlantic Ocean to Lake Chad through the Gulf of Guinea, is another unique tectonic feature of the African region and is the only example on Earth of an active intraplate alignment of tectonic-related volcanoes and intrusive massifs synchronously developed on both the oceanic and the continental crusts and linked to a common mantle source. The scientific debates around its origin can ultimately reveal how the interaction and energy transfer between the asthenosphere and lithosphere contribute to shaping our planet. The Cameroon Line is a unifying geological and biological gift linking many nations in Central Africa, and telling an important part of the autobiography of the continent (from about 70 million years) from geological, biological and socio-cultural perspectives (Anderson & de Wit, 2008; Henriques & Neto, 2015; Toteu et al., 2010). The IUCN *World Heritage Volcanoes* report of 2019 sees the Cameroon Line as worthy of consideration in the Tentative List of States Parties (Casadevall et al., 2019).

Despite the fact that tectonic processes cause major changes on the Earth's surface, they are poorly represented in the list of properties inscribed on the World Heritage List or even on the Tentative Lists. The cause of this might be the poor capacity of States Parties, or the fact that some expressions of tectonic processes such as volcanoes or erosion surfaces already constitute individual geological themes. However, the huge scale of some of the features (e.g. rift valleys, alpine ranges, oceanic trenches) also makes them politically and financially difficult to promote. It is also important to stress that the geological community have not done enough to demonstrate the prominent role geological processes have

played in shaping the landscape of the Earth, in impacting the development of biodiversity and the culture of people. This transpires well in the case of Sagarmatha National Park (Nepal) mentioned previously, which was inscribed on the World Heritage List under criterion (vii), despite the fact that the site description clearly recognises the importance of mountain building (i.e. 'tectonic' process). Clearly, States Parties must be encouraged to focus on and expose the geological processes that generated the appropriate environment for development of so many biological and cultural properties today inscribed on the World Heritage List. In this regard, all mountain ranges around the world, especially the Alpine, Himalayan and Andean collisional belts and rift valleys have produced a variety of ecosystems that have favoured the development of rich biological and cultural diversities. There is today a need to see beyond these end-products and make the tectonic processes themselves more visible.

Considering that most tectonic features on the Earth's surface appear as linear and transnational features (e.g. major faults, ocean ridges, mountain belts, rift and associated volcanoes), it might be necessary and more efficient for States Parties, individually or as group, to look into serial nominations as a mechanism that can associate different properties generated from the same tectonic process. However, one challenge may be the disparities (infrastructure, human resource and policies) that may exist between States Parties, with as a consequence, difficulty of preparing and implementing coherent and robust management plan for the inscribed property. At the opposite, it might be easier for one country having a specific tectonic feature that has generated several other outstanding geological, biological and/or cultural features to manage a property inscribed under serial nomination.

Theme 3:
Erosional systems

Piotr Migoń

Figure 10: Canaima National Park (Venezuela). The tabular hills and high escarpments of Canaima display significant karstic erosion of quartzites. © Natalino Russo / La Venta

What does the theme cover?

The theme 'Erosional systems' was not explicitly present in the 2005 report. One might argue that it is the equivalent of the 'Mountain systems' with partial overlap with the 'Arid and semi-arid desert systems', but there were already a number of World Heritage Properties inscribed under criterion (viii) which were neither mountains nor located in drylands but were erosional in nature. Additionally, a significant number of properties were inscribed in recognition of their scenic beauty (criterion (vii)), although their justifications clearly highlighted geomorphological features and processes more in line with criterion (viii). The relevance of 'Erosional systems' for criterion (viii) is twofold. First, erosional systems show "significant on-going geological (in fact, geomorphological) processes in the development of landforms" and secondly, these processes may produce "significant geomorphological or physiographical features."

Erosional systems are understood as including landscapes and landforms produced by the combined action of various surface processes that are not covered by the specialised Themes 6 'Cave and karst systems', 7 'Coastal systems', 9 'Glacial and periglacial systems' and 10 'Desert and semi-desert systems' elsewhere in this report. Volcanic systems (Theme 4), in turn, are predominantly constructional. Thus, from the process-based perspective, erosional systems are shaped by (a) weathering, (b) mass movements of various kind, (c) slope runoff, (d) fluvial erosion and e) non-karstic subsurface processes such as piping. Among them, weathering, mass movements and fluvial erosion are the most important agents of shaping the land surface. All these processes lead to deposition of material eroded from elsewhere allowing depositional forms such as talus and alluvial fans to locally dominate the landscape (e.g. in the valley floors). Nevertheless, erosion, in the broad sense, is the primary factor behind the scenery. In parallel to the above, the meaning of erosional systems may be also explained by products, i.e. landscapes and landforms produced by the processes listed above.
At the regional scale, these systems include non-glaciated mountains, plateaus and escarpments, strongly dissected uplands, including badlands, inselberg landscapes, peneplains and solitary elevations isolated by erosional lowering of the surrounding terrains. Characteristic medium-size landforms within erosional systems include rock cities and ruiniform relief, tors (crags), rock cliffs, gully networks, canyons and landform assemblages produced by landslides and piping.

Table 3: World Heritage Properties inscribed under criterion (viii) with Theme 3 as the major theme for inscription, or as an ancillary theme.

Criterion (viii) Properties Inscribed Principally Under Theme 3	Date Inscribed (extension)	Criterion (viii) Properties for which Theme 3 was an Ancillary Theme for Inscription	Date inscribed (extension)
Grand Canyon National Park, United States of America	1979	Nahanni National Park, Canada	1978
Durmitor National Park, Montenegro	1980 (2005)	Great Smoky Mountains National Park, United States of America	1983
Tassili n'Ajjer, Algeria	1982	Gondwana Rainforests of Australia, Australia	1986 (1994)
Uluṟu-Kata Tjuṯa National Park, Australia	1987 (1994)	Mosi-oa-Tunya / Victoria Falls, Zambia, Zimbabwe	1989
Canaima National Park, Venezuela	1994	Three Parallel Rivers of Yunnan Protected Areas, China	2003
Purnululu National Park, Australia	2003		
The Dolomites, Italy	2009		
China Danxia, China	2010		
Lena Pillars Nature Park, Russian Federation	2012		

Erosional systems are not limited to any specific bedrock type, although by virtue of strength, some rock types tend to support distinctive, often spectacular erosional systems more often than others do. Moreover, these systems appear and develop in different ways, depending on rock type. Therefore, to account for the diversity of landforms and controls and to facilitate comparative analyses, it is useful to consider several distinctive rock-controlled erosional systems, such as granite landscapes, sandstone and conglomerate landscapes, mudstone and tuff badlands, as well as ancient volcanic terrains, which may be plateaus or pointed elevations (necks).

What had been listed as World Heritage by 2005?

At the time of the 2005 report, though not identified as such at the time, six World Heritage Properties inscribed under criterion (viii) fit the descriptive definition of Erosional systems adopted in the new thematic approach of this study, and a further five properties relate to Erosional systems as an ancillary theme (Table 3; Annex 1)

In addition, the effects of long-term erosion are evident in several other properties inscribed under criterion (viii), although these may be also be represented under other themes:

1. Tasmanian Wilderness, Australia, (vii), (viii), (ix) and (x) – mountainous landscapes with dissected terrains and plateaus (classified as 'Glacial and periglacial systems', Theme 9);
2. Gondwana Rainforests of Australia, Australia, (viii), (ix) and (x) – part of Great Escarpment;
3. Dinosaur Provincial Park, Canada, (vii), (viii) – chiefly paleontological site (Theme 1), but also an excellent example of badland topography;
4. Canadian Rocky Mountain Parks, Canada, (vii), (viii) – fossil site (Theme 1) with diverse mountainous topography, including widespread glacial features;
5. Three Parallel Rivers of Yunnan Protected Areas, China, (vii), (viii), (ix) and (x) – deeply carved valleys of major rivers within mountainous setting;
6. Great Smoky Mountains National Park, United States of America, (vii), (viii), (ix) and (x) – dissected mountainous terrain, non-glacial.

What has been listed as World Heritage since 2005?

Since the 2005 report, an additional three properties have been inscribed under criterion (viii) because of their erosional features:

1. China Danxia, China, (vii) and (viii)– diverse erosional topographies on continental red beds, predominantly sandstone and conglomerate;
2. The Dolomites, Italy, (vii) and (viii) – rock-controlled cliffs and plateaus, with additional role of glaciation;
3. Lena Pillars Nature Park, Russian Federation, (viii) – rock formations due to differential erosion along riverside margins.

Is the thematic advice we have at present sufficient for this theme?

There has been no supplementary advice to date on this newly proposed theme. Reasons for not inscribing the localities listed above are probably complex but it certainly has to be observed that many of these inscriptions predate the year 2000, reflecting contemporaneous focus on scenic values rather than geodiversity and geoheritage. In some instances, at least, insufficient scientific understanding may have been an additional factor for not considering criterion

Figure 11: Tassili n'Ajjer (Algeria). The sandstone plateaux and escarpments of Tassili n'Ajjer are highly dissected with a range of erosional features. © Mohammed Beddiaf. Source: UNESCO

(viii). In this context, it is worth mentioning that post-2005 scholarly monographs on granite landscapes and sandstone landscapes, published by leading academic publishing houses, may now provide much better scientific background for nominations under criterion (viii).

How well is the theme now represented on the World Heritage List, including its geographical distribution?

Erosional systems are currently represented by about 35 properties, with 29 of them inscribed under criteria (vii) and/or (viii). Among them, distinctive sandstone and conglomerate erosional landscapes, from plateaus to inselbergs, are fairly well represented – 12 properties, including six under criterion (viii). However, the majority of them occurs in drylands (eight cases, including three in north Africa and three in Australia) and only two were established in humid terrains. Three properties represent granite landscapes, all in China and representing similar topography, none inscribed explicitly under criterion (viii). Three properties cover ancient volcanic terrains, mostly plateaus. Great Escarpments and badlands are represented by two examples each. Finally, five properties may be classified as mountainous landscapes, with no specific connection to any particular rock type. Overlap with glacial and periglacial systems is evident in some of these properties. The Dolomites (Italy) and Lena Pillars Nature Park (Russian Federation) are distinctive individual cases. Thus, whereas overall representation of erosional systems may seem adequate, there are significant gaps, both thematic and geographical.

Considering the diversity of erosional systems, the following missing themes may be identified:

- erosional landscapes developed on clastic rocks, mainly sandstone and conglomerates, in semi-humid and humid areas, to counterbalance an over-representation of those in arid and semi-arid terrains. They are likely to develop by a different suite of dominant processes than their arid counterparts;
- granite topographies are evidently under-represented, especially if criterion (viii) alone is considered. Existing properties are all mountainous and all from one region (east China), whereas inselberg landscapes, domed mountains, uplands (plateaus) with tors, spectacular boulder fields are missing;
- badlands are another under-represented type of erosional system, especially given lithological diversity of badlands. Mudrocks and cemented gravel deposits are known to host spectacular badland landscapes;
- entirely non-glacial mountain systems are poorly represented and there is a room for nominations which would emphasise complexity and integrity of mountain systems, preferably on lithologically diverse bedrock.

In terms of geographical coverage, properties inscribed principally under Theme 3 occur in Europe and North America (4), Asia and the Pacific (3) and one each in Arab States and Latin America and the Caribbean. Sub-Saharan Africa is represented by only one property but which is not inscribed explicitly under criterion (viii). High latitudes are another

geographical gap (two properties only, one under criterion (vii)), where it may be assumed that cold-climate processes will produce erosional systems different from those in low latitudes, whether humid or arid. Some of these gaps may be filled by re-nominating some of existing World Heritage Properties, adding criterion (viii) to the cultural criteria used before.

Any key issues (things to avoid, lessons learned, considerations like serial properties, relevance to other criteria, any 'big stories' missing, key properties for this theme that would meet criterion (viii) that are listed under other criteria, interplay with biodiversity, culture)?

Impressive erosional landscapes may be found within World Heritage Properties inscribed under criteria (ix) and (x) (e.g. Greater Blue Mountains Area (Australia) and Western Ghats (India)) or solely under criteria pertinent to cultural heritage (e.g. tall granite domes, which form the stage for Rio de Janeiro: Carioca Landscapes between the Mountain and the Sea (Brazil), as well as the Serra da Capivara National Park (Brazil), the Matobo Hills (Zimbabwe), Rock-Art Sites of Tadrart Acacus (Libya) or Group of Monuments at Hampi (India)). An emerging point here is that the coverage of erosional systems by existing World Heritage Properties is much larger than the examination under criterion (viii) alone would suggest. Consequently, gap analyses should consider these properties as well.

Additionally, in a few examples, criterion (viii) was proposed to justify inscription but was not accepted (e.g. Mount Sanqingshan National Park (China), (vii) and Wadi Rum Protected Area (Jordan), (iii), (v) and (vii)). In other cases, criterion (viii) could have been used but was not proposed, possibly because the nominated property did not readily fit any of the 13 Earth science themes proposed by the 2005 report. In fact, an equally large number of properties representing excellent examples of erosional systems have been inscribed under criterion (vii), not (viii), even if the OUV statements relate directly to the effects of on-going erosion and significant landforms produced by it. These properties include:

1. Kakadu National Park, Australia, (i), (vi), (vii), (ix) and (x) – dissected sandstone plateau and escarpments;
2. Ennedi Massif: Natural and Cultural Landscape, Chad, (iii), (vii) and (ix) – sandstone plateaus, canyons and rock arches;
3. Mount Taishan, China, (i), (ii), (iii), (iv), (v), (vi) and (vii) – granite mountainous terrain;
4. Mount Huangshan, China, (ii), (vii) and (ix) – granite mountainous terrain;
5. Wulingyuan Scenic and Historic Interest Area, China, (vii) – intricately dissected sandstone and limestone upland, with multitude of tall rock towers and spires;
6. Mount Sanqingshan National Park, China, (vii) – granite mountainous terrain;
7. Simien National Park, Ethiopia, (vii) and (x) – dissected lava plateau;
8. Meteora, Greece, (i), (ii), (iv), (v) and (vii) – isolated residual hills carved out of conglomerate;
9. Wadi Rum Protected Area, Jordan, (iii), (v) and (vii) – sandstone massifs and rock arches;
10. Maloti-Drakensberg Park, Lesotho and South Africa, (i), (iii), (vii) and (ix) – Great Escarpment capped by basaltic lavas;
11. Cliff of Bandiagara (Land of the Dogons), Mali, (v) and (vii) – plateau, cliffs and plains in sandstone rocks;
12. Air and Ténéré Natural Reserves, Niger, (vii), (ix) and (x) – residual volcanic massifs;
13. Putorana Plateau, Russian Federation, (vii) and ix) – ancient lava plateau;
14. Göreme National Park and the Rock Sites of Cappadocia, Turkey, (i), (iii), (v) and (vii) – strongly eroded tuffs and lacustrine deposits, multiple hoodoos and badland landscape.

Theme 4:
Volcanic systems

Tom Casadevall

Figure 12: Volcanoes of Kamchatka (Russian Federation). Kamchatka is one of the most outstanding volcanic regions in the world, with a high density of active volcanoes, a variety of types, and a wide range of related features. The six sites included in the serial designation group together the majority of volcanic features of the Kamchatka peninsula. The interplay of active volcanoes and glaciers forms a dynamic landscape of great beauty. © UNESCO

What does the theme cover?

Volcanoes are widely understood by the public as wonders of the planet; they are central to the formation, evolution and sustenance of biological systems; they form some of our deepest and most significant cultural attachments to the land; and they attract large numbers of visitors for their aesthetic appeal. The theme Volcanic systems was recognised in the 2005 report (numbered as Theme 2). Furthermore, volcanic systems were the subject of the 2009 volcano thematic study by Wood (2009). In 2019, IUCN published an updated report on *World Heritage Volcanoes* (Casadevall et al., 2019), which we draw on here for this discussion.

This study continues to consider Volcanic systems as a distinct theme. Most geological themes encompass millions or billions of years of Earth history. The Volcanic systems theme includes volcanoes and volcanic features found on Earth in both the marine and terrestrial environments. While these features can be from any period of Earth history, from the oldest volcanic rocks (4.2 billion years old) to the youngest eruptions, the majority of volcanic properties, by their nature, typically only preserve the most recent geological time frames. Active volcanoes encompass those active in the Holocene Epoch (the last 11,700 years). The distinctive attributes of volcanic properties are of geoheritage value but, significantly, they also frequently demonstrate associated aspects of cultural, spiritual, biological, aesthetic and educational value. Thus, in a number of cases volcanic areas may be protected as World Heritage solely for these other attributes, without direct recognition of the volcanic geoheritage as being the basis of OUV (Casadevall et al., 2019).

What had been listed as World Heritage by 2005?

Volcanic landscapes are among the most recognisable properties on the World Heritage List. Of 1,211 World Heritage Properties in 2019, 83 (7.4%) have significant volcanic features (Casadevall et al., 2019). However, of these, only 26 properties have been inscribed under criterion (viii). Utilising the current themes, 14 properties inscribed on the List by 2005 had gained their recognition mainly or solely under the present Theme 4 (Table 4; Annex 1).

Table 4: World Heritage Properties inscribed under criterion (viii) with Theme 4 as the major theme for inscription, or as an ancillary theme.

Criterion (viii) Properties Inscribed Principally Under Theme 4	Date Inscribed (extension)	Criterion (viii) Properties for which Theme 4 was an Ancillary Theme for Inscription	Date inscribed (extension)
Yellowstone National Park, United States of America	1978	El Pinacate and Gran Desierto de Altar Biosphere Reserve, Mexico	2013
Galápagos Islands, Ecuador	1978 (2001)	Barberton Makhonjwa Mountains, South Africa	2018
Ngorongoro Conservation Area, United Republic of Tanzania	1979 (2010)		
Virunga National Park, Democratic Republic of the Congo	1979		
Sangay National Park, Ecuador	1983		
Giant's Causeway and Causeway Coast, United Kingdom of Great Britain and Northern Ireland	1986		
Hawaii Volcanoes National Park, United States of America	1987		
Tongariro National Park, New Zealand	1990 (1993)		
Volcanoes of Kamchatka, Russian Federation	1996 (2001)		
Heard and McDonald Islands, Australia	1997		
Macquarie Island, Australia	1997		
Morne Trois Pitons National Park, Dominica	1997		
Isole Eolie (Aeolian Islands), Italy	2000		
Pitons Management Area, Saint Lucia	2004		
Jeju Volcanic Island and Lava Tubes, Republic of Korea	2007		
Teide National Park, Spain	2007		
Papahānaumokuākea, United States of America	2010		
Mount Etna, Italy	2013		
Vatnajökull National Park - dynamic nature of fire and ice, Iceland	2019		

What has been listed as World Heritage since 2005?

Since the 2005 report an additional five volcanic properties have been inscribed under criterion (viii) primarily utilising Theme 4 (Table 4; Annex 1). Three of these inscriptions were added following the volcano thematic study of 2009 (Wood, 2009). Furthermore, since 2005 (and 2009) two nominations of volcanic properties were advanced but were not recommended for inscription as volcano-related World Heritage (Wudalianchi Scenic Spots (China) and Chaîne des Puys – Limagne fault tectonic arena (France), the latter was ultimately inscribed in 2018 for its tectonic features).

Is the thematic advice we have at present sufficient for this theme?

The *World Heritage Volcanoes* report, Casadevall et al. (2019), provides revised, comprehensive and up to date advice to States Parties on the application of criterion (viii) to volcanic properties, and replaces the 2005 study as the definitive thematic guidance going forward. The advice includes the use of the classification system and feature identification presented in this study to the nomination of volcanic properties under criterion (viii), including a checklist that can also be used by the reviewers of the nomination. The advice also describes a method for developing a comprehensive global comparative analysis to support the application for Listing in relation to volcanic systems, this being a point that has been problematic in a number of nominations, and is central to the application and review process in establishing the potential for OUV.

How well is the theme now represented on the World Heritage List, including its geographical distribution?

As noted above there are now 83 properties on the World Heritage List with significant volcanic values. Of these, 19 are volcanic properties, where Theme 4 provides the primary rationale under criterion (viii), and two additional properties have used it as an ancillary rationale. Within these 21 properties there are many important gaps in geographical distribution, as well as gaps in their distribution by geo-tectonic setting. The

Figure 13: Ngorongoro Conservation Area (United Republic of Tanzania). The Ngorongoro Conservation Area spans vast expanses of highland plains, savannah, savannah woodlands and forests centred on the spectacular Ngorongoro Crater, Africa's largest caldera. © Patrick Mc Keever

regional distribution of volcanic properties is: Europe and North America (8), Asia and Pacific (4), Africa (2) and Latin America and the Caribbean (5).

The 2019 volcano theme study outlines a series of recommendations to fill the thematic and geographical gaps on the World Heritage List. The southwestern Pacific island arcs are noted as unrepresented on the List. The Andes of western South America is the most prominent example of continental arc volcanism and yet is poorly represented. For divergent margin properties, the Great Rift Valley of Africa and its northern continuation in the Red Sea and Gulf of Aden are poorly or not represented. Submarine volcanic systems are dominantly rift systems and are not represented. Volcanism in back arc basins is unrepresented although there are outstanding examples in Argentina and the southwest Pacific. Collision zones are not represented. The two ancient volcanic terrains on the current List contain no continental flood basalts, ring dykes or subvolcanic feeder and storage systems, despite the importance of these terrains in creating and remaking the early continents and as components of most of the planet's major mass extinctions. Previously identified gaps in Archean granite-greenstone belts and komatiites and in modern mid-Atlantic Ridge volcanism have been addressed by Barberton Makhonjwa Mountains (South Africa, inscribed in 2018) and Vatnajökull National Park - dynamic nature of fire and ice (Iceland, inscribed in 2019).

Other under-represented aspects of Theme 4 include large caldera forming volcanic systems; stratovolcanoes found in several critical subduction zone environments (e.g. Andean and Cascadian zones; Indonesia-Philippine-Japanese subduction zones), and submarine volcanic features and volcanic rift systems. Conversely, monogenetic volcanic fields and basaltic volcanism should now be considered as well or fully represented on the List.

Any key issues (things to avoid, lessons learned, considerations like serial properties, relevance to other criteria, any 'big stories' missing, key properties for this theme that would meet criterion (viii) that are listed under other criteria, interplay with biodiversity, culture)?

No discussion of the global volcanic estate would be complete without mention of volcanism in the marine environment. Purely submarine volcanic features are not included on the World Heritage List, primarily because many of these features occur under what is known as the 'High Seas' where no State Party has legal jurisdiction. However, 70% of the Earth's surface is covered by water and is effectively a submarine environment and much of the Earth's active tectonism, including spreading centres, ridges, transform faults and subduction-related trenches are submarine. Bathymetric studies of the sea floor have revealed that this vast area is dotted with volcanoes, which recent studies (Hillier & Watts, 2007; Wessel et al., 2010; Kim & Wessel, 2011) estimate could number over three million, 39,000 of which rise to more than 1,000 m above the ocean

floor. With the increase in seafloor mining and other potentially destructive practices, some of these volcanic terrains are at risk.

Several marine reserves include areas of submarine volcanism and hydrothermal vent activity but, by and large, the volcanic features in these submarine environments are not adequately represented on the World Heritage List. The World Heritage Convention does not currently address areas beyond national jurisdiction (Abdulla et al., 2013; Freestone et al., 2016).

One impediment to managing and protecting properties in the submarine environments is that often there are no States Parties to claim jurisdiction and management responsibility over most of them. Thus, such properties fall more appropriately under 'Law of the Sea' jurisprudence. However, several submarine volcanoes representing submarine extensions of terrestrial volcanic systems (Loihi, USA and Oshima, Japan) do fall within territorial jurisdictions. The UNESCO/IUCN publication *World Heritage on the High Seas: An Idea Whose Time Has Come* (Freestone et al., 2016) discusses this topic primarily from the perspective of biological World Heritage, but many of the concepts therein also apply to geological World Heritage.

Casadevall et al. (2019), considers the absence of submarine volcanism from the World Heritage List to be a substantial gap in representation of the Earth's volcanic systems. However, they also recognise that filling this gap will depend upon additional international agreement and governance frameworks, and this represents a further reason to explore the extension of the application of the World Heritage Convention to the High Seas.

World Heritage Volcanoes (Casadevall et al., 2019) found that a significant number of volcanic properties on the World Heritage List are listed under other criteria than criterion (viii). In part this reflects the important cultural and historical values often assigned to volcanic features and eruptions by communities which may have witnessed eruptions or live in or on volcanic edifices which have attained a notable role in these cultures. In addition, a number of volcanic areas have important endemic plant communities with high degrees of biodiversity. Thus, many volcanic landscapes have been inscribed for their biodiversity under criteria (ix) and (x).

Theme 5:
River, lake and delta systems

Ulrika Åberg

Figure 14: Plitvice Lakes National Park (Croatia). The waters flowing over the limestone and dolomites have, over thousands of years, deposited travertine barriers, creating natural dams, which in turn have created a series of beautiful lakes, caves and waterfalls. These geological processes continue today. © Ko Hon Chiu Vincent. Source: UNESCO

What does the theme cover?

The theme covers fluvial, lacustrine and deltaic landscapes and their associated features. These are systems resulting from large-scale fluvial processes, which have formed and influenced the development of valleys, flood plains, river corridors, wetlands, lakes and deltas, along with instream features and morphology (Ferrier & Jenkins, 2010). The theme includes foremost alluvial landscapes and depositional features, while erosional features, such as river canyons, are covered primarily by Theme 3. However, spectacular features such as waterfalls are included under this theme. In terms of deltas, this theme only covers the special cases of inland and inverted deltas, while coastal deltas are covered within Theme 7. There is also some overlap with Theme 9, as many important fluvial, lacustrine and deltaic processes and landforms occur in glacial landscapes. The River, lake and delta systems theme is equivalent to the 'Fluvial, lacustrine and deltaic systems' theme from the 2005 report.

The main driving process for the formation of all inland waters is the hydrological cycle. Water evaporates from the oceans and precipitates over the continents, where it flows back to the sea along rivers and streams, reworking large amounts of sediments and forming some of our most familiar fluvial landforms. Some of the water resides in wetlands or lakes for many years, or in ice caps for thousands or millions of years (Moss, 2010).

River processes shape the Earth's surface while responding to sudden events (earthquakes, volcanic eruptions, mega floods) and/ or progressive change (continental uplift, change in climate and precipitation). Climate and precipitation are the main factors influencing the dynamics and evolution of river systems, with this history embedded into relict forms and features. The fluvial geomorphology of rivers adjusts both to varying flow patterns and vegetation cover. During drier geological periods, vegetation cover and sediment transport decreases and rivers transform into new types. Examples of this are underfit streams, which have channels set in valleys formed by much larger river systems during wetter periods (Fryirs & Brierley, 2012). Apart from recording past climate events, rivers also demonstrate a huge diversity of types,

Table 5: World Heritage Properties inscribed under criterion (viii) with Theme 5 as the major theme for inscription, or as an ancillary theme.

Criterion (viii) Properties Inscribed Principally Under Theme 5	Date Inscribed (extension)	Criterion (viii) Properties for which Theme 5 was an Ancillary Theme for Inscription	Date inscribed (extension)
Nahanni National Park, Canada	1978	Canaima National Park, Venezuela	1994
Everglades National Park, United States of America	1979	Lake Baikal, Russian Federation	1996
Plitvice Lakes National Park, Croatia	1979 (2000)	Three Parallel Rivers of Yunnan Protected Areas, China	2003
Willandra Lakes Region, Australia	1981	Tajik National Park (Mountains of the Pamirs), Tajikistan	2013
Río Plátano Biosphere Reserve, Honduras	1982		
Mosi-oa-Tunya / Victoria Falls, Zambia, Zimbabwe	1989		

processes and physiographic features. For example, natural floodplains contain a high complexity of various physical features such as meander bends, levees, cutbanks, pointbars, relict channels, oxbow lakes, ponds, islands, channel braiding, alluvial fans, inland deltas, swamps and marshes.

What had been listed as World Heritage by 2005?

In the 2005 report, it was noted that there were 71 World Heritage Properties inscribed under criterion (viii). Using the present themes, the principal attributes of the OUV of six properties are assigned to the 'Fluvial, lacustrine and deltaic systems' theme. One of these, Everglades National Park (United States of America), share its main theme with Theme 7 (Coastal systems). Up to 2005, another three properties had ancillary attributes of OUV assigned to Theme 5 (Table 5; Annex 1).

Evidently, many properties on the World Heritage List demonstrate significant values related to the River, lake and delta systems theme, but are inscribed under criteria other than criterion (viii). In this updated review, about 30 properties inscribed under criteria other than (viii) prior to 2005, were found to demonstrate values of Theme 5. The statements of OUV for some of these properties (for example Pantanal Conservation Area (Brazil), and Mana Pools National Park, Sapi and Chewore Safari Areas (Zimbabwe)) are directly linked to significant fluvial, lacustrine and deltaic forms and processes, and contain examples of some of the world's most prominent systems relating to this theme.

Several World Heritage Properties contain the full length of rivers or the majority of their lengths and catchments, for example, Kakadu National Park (Australia), but only the Río Plátano Biosphere Reserve (Honduras) is inscribed under criterion (viii).

What has been listed as World Heritage since 2005?

Since 2005, no properties have been inscribed on the World Heritage List with their principal attributes of OUV assigned to the River, lake and delta systems theme and only one property (Tajik National Park (Mountains of the Pamirs), (Tajikistan)) utilises Theme 5 as an ancillary theme in its statement of OUV. Among properties inscribed after 2005 under criteria other than criterion (viii), ten are identified to demonstrate significant values directly related to Theme 5. Among these are one of the world's most important inland deltas, the Okavango Delta (Botswana), and the saline, hyper-saline and freshwater Lakes of Ounianga (Chad). It is clear that many more properties on the World Heritage List, other than those inscribed under criterion (viii), demonstrate significant and even outstanding river, lake and delta systems values.

Is the thematic advice we have at present sufficient for this theme?

There is one early study (Thorsell et al., 1997) on wetland and marine areas on the World Heritage List, which also provides a list of 41 prospective sites with potential OUV. Some of these have now been inscribed (for example, Pantanal Conservation Area (Brazil), Landscapes of Dauria, (Mongolia and Russian Federation) and Okavango Delta (Botswana)), however, only a few, such as Wadden Sea (Denmark, Germany and Netherlands) (see Theme 7), under criterion (viii). World Heritage Properties with OUV under Theme 5 are still poorly represented on the World Heritage List. Conversely, although some of the world's most prominent properties under this theme are inscribed, their attributes and values have not been recognised as OUV under criterion (viii). Some reasons might be previously vague descriptions of the theme, unawareness that the OUV of river, lake and delta systems are recognised under criterion (viii) and inadequate scientific understanding or recognition of these systems. This lack of recognition requires attention. As no properties have been inscribed under Theme 5 since 2005, this clearly shows that additional upstream support and a gap analysis on the theme are needed to address this discrepancy.

How well is the theme now represented on the World Heritage List, including its geographical distribution?

The theme is clearly under-represented among properties inscribed under criterion (viii). Presently, only six properties have been recognised for their OUV as river, lake and delta systems.

Figure 15: Nahanni National Park (Canada). Located along the South Nahanni River, this property is one of the most spectacular wild rivers in North America. The park contains deep canyons and huge waterfalls. The geomorphology of the property is outstanding in its wealth of form and complexity of evolution. The park hosts the World's foremost example of karst development in cold climate conditions, but fluvial processes and features predominate. Within the property are examples of almost every known characteristic of rivers. Geological and geomorphological features include the abandoned meanders of ancient rivers, now raised high above present river levels. © Ko Hon Chiu Vincent. Source: UNESCO

Despite having three of the largest and most important inland deltas already inscribed on the World Heritage List (Wood Buffalo National Park (Canada), the Okavango Delta (Botswana) and The Ahwar of Southern Iraq: Refuge of Biodiversity and the Relict Landscape of the Mesopotamian Cities (Iraq)), none of these properties were inscribed under criterion (viii) or recognised for their extremely important and valuable deltaic processes. Likewise, although the World Heritage Properties of Iguazu National Park (Argentina) and Iguaçu National Park (Brazil) conserve the largest and one of the most spectacular waterfall systems in the world, this has not been recognised as a value under criterion (viii).

Terrestrial fossil properties inscribed under Theme 1, notably Miguasha National Park (Devonian), Joggins Fossil Cliffs (Carboniferous) and Dinosaur Provincial Park (Cretaceous), all in Canada, occur in well studied fluvial, lacustrine and deltaic deposits, but this is not included as part of their OUV.

Any key issues (things to avoid, lessons learned, considerations like serial properties, relevance to other criteria, any 'big stories' missing, key properties for this theme that would meet criterion (viii) that are listed under other criteria, interplay with biodiversity, culture)?

Freshwater is fundamental to life on Earth and hydromorphological processes have shaped much of the Earth's surface as we see it today. The importance of river (and other freshwater) systems for the evolution of life on land and human societal development is unparalleled. The characteristics of freshwater bodies are highly determined by the climate and their relict forms and sediment archives are therefore also of immense importance for understanding past climatic events and changes. Until now, only Willandra Lakes Region (Australia) has been inscribed for its OUV of showing past major changes in Earth's climate history and evolution.

Large rivers cover long distances and vast areas and it is often not feasible to include the whole catchment within a World Heritage nomination. Designation of OUV attributes such as the world's longest river or highest discharge river is difficult to achieve but could be done through serial properties and/ or transboundary nominations. To cover the 'big stories', we should focus on the few natural rivers left and the textbook examples of alluvial and depositional features, as well as past climatic records, that these systems demonstrate. Large, relatively intact, meandering systems can still be found in the Amazon and Congo basins, as well as in northern Siberia and China, while extensive braided river systems are found in North America, New Zealand's South Island and the Himalayas. The flow of many rives has been impeded by human activity and natural, free-flowing rivers[2] are now confined to the Arctic (Canada and Russian Federation) and the Amazon and Congo basins, as well as

a few examples in, for example, Australia and Papua New Guinea (Grill et al., 2019; WWF, 2019).

Theme 5 is highly relevant for other criteria, and as discussed earlier, some of the world's most outstanding river, lake and delta systems are inscribed under criteria other than criterion (viii). Of greatest importance is undeniably that these properties and their physical, biological and evolutionary processes are now protected for future generations, however, it would be an advantage if they were also recognised for their OUV under criterion (viii). Freshwater systems contain some of the most threatened habitats on the planet and are losing biodiversity twice as fast as any terrestrial or marine systems. Despite only covering about 1% of the terrestrial surface, these systems support about one-third of all known vertebrate species (Dye et al., 2019). River, lake and delta systems often present exceptional natural beauty, significant on-going ecological and biological processes and contain significant natural habitats for in-situ conservation of biological diversity and threatened species, and are therefore highly relevant for all the other natural (including some of the cultural) criteria.

Lastly, it should be noted that there are particularly important links to be made in application of this theme through connections to the implementation of the 1971 Ramsar Convention, which allows for the recognition of wetlands of international importance. IUCN and the Ramsar Convention Secretariat have frequently collaborated on implementation, including the joint work on the only thematic study on this theme (from 1997). However, the clear need for further thematic advice could be advanced by IUCN, in conjunction with Ramsar.

2. **Free Flowing Rivers, 2019 -** http://freeflowingriver.org/

Theme 6:
Cave and karst systems

Paul Williams and Kyung Sik Woo

Figure 16: Škocjan Caves (Slovenia). Located in the 'classical' karst of Europe, the property comprises a sinking river at the end of blind valley, the exposed course of the underground river flowing across the base of deep collapse depressions, and a large river cave with a high canyon passage. It is representative of the input of an allogenic river into a karst system. © Limes.Media, Tim Schnarr. Source: UNESCO

What does the theme cover?

The theme covers systems developed predominantly by the process of dissolution of soluble rocks. This mainly involves carbonate rocks (limestone, dolomite, marble) and evaporite rocks (gypsum, salt). In these terrains drainage disappears in enclosed depressions, rivers sink underground, and caves are signature landforms. Some sandstone landscapes are also included because these rocks can become relatively soluble under subtropical and tropical conditions. Natural processes involved in the development of caves and karst systems are explained by Ford & Williams (2007, 2011) and Palmer (2007).

What had been listed as World Heritage by 2005?

At the time of the 2005 report, 45 properties with internationally significant cave and karst features had been inscribed on the World Heritage List. Amongst these were 25 considered to have outstanding karst features, yet only eight were recognised as having OUV primarily under Theme 6 with an additional seven properties using it as an ancillary theme (Table 6; Annex 1). One additional property with OUV was lava pseudokarst, recognised under criterion (viii) and having karst-like cave decorations developed within lava tubes formed through volcanic processes.

What has been listed as World Heritage since 2005?

By 2019, the number of properties with internationally significant cave and karst features on the World Heritage List had increased by two properties that adopt karst as their main theme and a further two that utilise it as an ancillary theme (Table 6; Annex 1). It is evident that the outstanding cave and karst qualities of several properties were not appreciated either by some parties responsible for considering these nominations. This points to the need for more upstream advice to assist in the recognition of significant karst values before nominations are made. Sometimes the most appropriate nomination configuration (single area/serial nomination/transnational nomination) was not identified at the time of inscription, and so adjustments have needed to be made to boundaries some years later.

Is the thematic advice we have at present sufficient for this theme?

The 2005 report contained excellent and focused advice and enabled States Parties to achieve a global overview regarding

Table 6: World Heritage Properties inscribed under criterion (viii) with Theme 6 as the major theme for inscription, or as an ancillary theme.

Criterion (viii) Properties Inscribed Principally Under Theme 6	Date Inscribed (extension)	Criterion (viii) Properties for which Theme 6 was an Ancillary Theme for Inscription	Date inscribed (extension)
Mammoth Cave National Park, United States of America	1981	Nahanni National Park, Canada	1978
Škocjan Caves, Slovenia	1986	Plitvice Lakes National Park, Croatia	1979 (2000)
Ha Long Bay, Viet Nam	1994 (2000)	Canadian Rocky Mountain Parks, Canada	1984 (1990)
Caves of Aggtelek Karst and Slovak Karst, Hungary, Slovakia	1995 (2000)	Canaima National Park, Venezuela	1994
Carlsbad Caverns National Park, United States of America	1995	Pyrénées - Mont Perdu, France, Spain	1997 (1999)
Desembarco del Granma National Park, Cuba	1999	Lorentz National Park, Indonesia	1999
Gunung Mulu National Park, Malaysia	2000	Purnululu National Park, Australia	2003
Phong Nha-Ke Bang National Park, Viet Nam	2003 (2015)	Jeju Volcanic Island and Lava Tubes, Republic of Korea	2007
South China Karst, China	2007 (2014)	Lena Pillars Nature Park, Russian Federation	2012
Trang An Landscape Complex, Viet Nam	2014		

the protection of geological World Heritage and the contribution that they might make. In addition to the 2005 report, in 2008 IUCN published a separate report on *World Heritage Caves and Karst: a Thematic Study*, which was a global review of karst World Heritage Properties (Williams, 2008). That thematic review of Caves and Karst was noted by several States Parties and encouraged a cautious consideration of the appropriateness or otherwise of possible nominations (Lena Pillars Nature Park (Russian Federation) in 2012 and the Trang An Landscape Complex (Viet Nam) in 2014), and stimulated a new entry on the Tentative List (Salt Domes of Iran 2017). The net effect of both reports was probably to encourage a total of about ten new inscriptions in this theme. However, there has been no progress regarding nominations in relation to gypsum karst. The 2008 study remains current and appropriate in guiding towards the completion of the World Heritage List under this theme of criterion (viii).

The 2008 thematic review pointed out that the World Heritage Committee had noted in 2007 [Decision 31 COM 8B.13]:

> "… that karst systems (including caves) are relatively well represented on the World Heritage List. Worldwide there are a large number of protected karst landscapes with caves and at a detailed level every one of these can assert that it is in some way unique. Therefore, in the interests of maintaining the credibility of the World Heritage List, IUCN considers that there is increasingly limited scope for recommending further karst nominations for inclusion on the World Heritage List. In particular, IUCN recommends that the World Heritage Committee should consider indicating clearly to States Parties that further karst nominations should only be promoted where:
>
> - There is a very clear basis for identifying major and distinctive features of outstanding universal value that has been verified by a thorough global comparative analysis;
> - The basis for claiming outstanding universal value is a significant and distinctive feature of demonstrable and widespread significance, and not one of many narrow and specialized features that are exhibited within karst terrains. IUCN recommends that States Parties considering karst nominations carry out an initial global comparative analysis **prior** to proceeding with the development of a full nomination, in order to minimize the possibilities of promoting a nomination that will not meet the requirements of the World Heritage Convention, including those concerning the conditions of integrity."

This advice was taken seriously by States Parties and is undoubtedly responsible for a reduction in the rate of nomination of cave and karst properties. Furthermore, this theme illustrates, in the nomination of the South China Karst (China), a particularly important example of the recognition of OUV through a serial approach, by assembling in a thoroughly planned process the most outstanding examples of karst sites that illustrate one of the two great karst regions of Earth. This is a model that has also been recommended in the thematic study in the Dinaric Karst, the other of those two great regions.

How well is the theme now represented on the World Heritage List, including its geographical distribution?

The theme is well represented on the World Heritage List (Annex 1) and has a wide, but unevenly distributed geographical distribution. Two points are significant here.

Figure 17: South China Karst (China). Seven sites of a serial nomination that represent karst evolution in southern China includes Shilin (stone forests on a rolling plateau in Yunnan); Jinfoshan (an isolated high plateau with huge horizontal caves suspended above deep surrounding valleys); Wulong (plateau karst with spectacular tiankeng, natural bridges, deep caves and gorges); Shibing (unusual cone karst development in dolomite bedrock); Libo (extensive forested cone karst (fengcong and fenglin), poljes, gorges and caves with Huanjiang being an extension of the protected area); Guilin (the culmination of subtropical karst development with spectacular cones and towers beside the River Li). These areas provide type-sites for their principal karst features. © IUCN/ Jim Thorsell

Firstly, the global distribution of karst rocks is the first determinant of where cave and karst World Heritage Properties can be located; hence, the properties shown on Figure 18 are mapped against a background of outcrops of carbonate and evaporite rocks (Goldscheider et al., 2020). These rocks are distributed unevenly, and the world distribution of evaporites is also uneven. Thus, we cannot expect an even global distribution of karst properties.

Secondly, cave and karst development depend on the operation of chemical processes driven by water and its temperature. Rainfall is the primary driver, but the rate of dissolution is enhanced if it is also warm. Hence, limestone locations that are wet, warm and forested have excellent caves and karst, which accounts for where most caves and karst World Heritage Properties are found. However, global climates change over time, so important palaeokarst is sometimes found in places that were once wet but under modern conditions are inimical to karst and cave evolution. This is the case in many temperate to subtropical arid lands where caves, acting as Nature's vaults, contain rich histories of more benign environments and climates in the past. Some cold properties of the subarctic were also once warmer and have palaeokarst features developed during past milder humid conditions.

The 2008 thematic review of caves and karst identified significant gaps in the geographical distribution of karst World Heritage Properties and pointed to a gap in semi-arid and periglacial environments. Only one inscription, Lena Pillars Nature Park (Russian Federation), has since contributed to filling that gap. Central Asia, the Middle East, Africa and South America remain seriously under-represented. It was also pointed out that an important gap exists in the representation of evaporite terrains (salt and gypsum). This remains the case. Also despite Shibing Karst in China being a dolomite terrain, a gap remains regarding well-developed caves in dolomite.

One 'big story' that is unrepresented, but to which caves and karst can contribute, is that of climates of the past. Palaeokarst properties that contain important stories about past conditions on Earth are not explicitly represented on the World Heritage List, although several World Heritage karst properties contain caves with excellent palaeoclimate archives. Global climate is never static and while ice caps and seafloor sediments contain major climate archives, the continents are under-represented. Between the poles, the best source of terrestrial palaeoclimate records is caves (they are also one of the best sources of hominid remains). Further, cave records are also very much easier to date than other archives. For example, caves in the arid Nullarbor Plains of Australia have yielded mid-Pliocene speleothems containing pollen indicative of a past forested environment in association with rare mega-faunal remains. The arid cave and karst properties of Central Asia and Africa could hold evidence of similar stories. A cave in the island of

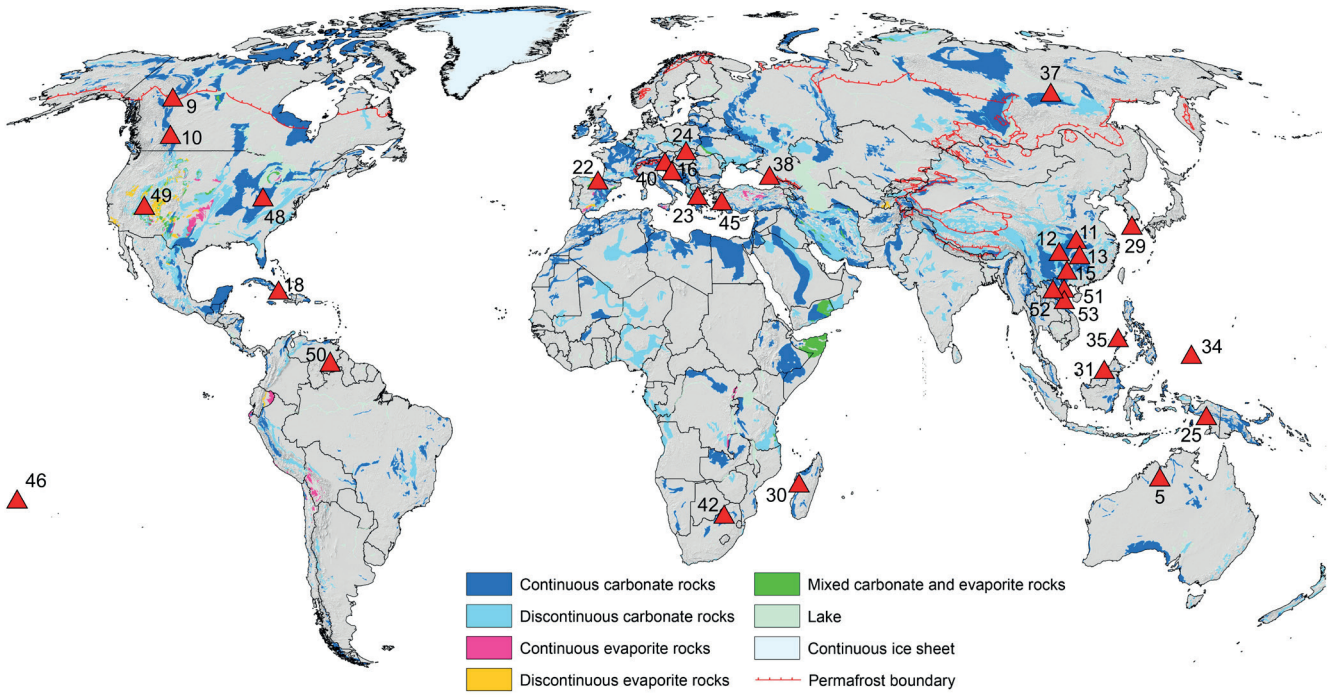


Figure 18. Distribution of karstifiable rocks and potential karst aquifers across the world (with permission from Goldscheider et al., 2020) with red triangles depicting the locations of World Heritage Properties with karst OUV, their numbers referring to the list of World Heritage karst sites (see Annex 4). © Goldscheider et al. (2020)

Mallorca, Spain, has yielded a precisely dated history of sea level change in the mid-Pliocene at a time when the Earth's temperatures were two or three degrees higher than present. Thick guano deposits in caves have never been investigated in detail for their palaeoecological record, although they have long been recognised as sources of minerals.

Any key issues (things to avoid, lessons learned, considerations like serial properties, relevance to other criteria, any 'big stories' missing, key properties for this theme that would meet criterion (viii) that are listed under other criteria, interplay with biodiversity, culture)?

The key issue to emerge from this review is that many properties nominated for other reasons contain excellent caves and karst (Annex 1). Consequently, important karst areas are being conserved on the coat-tails of other criteria. This is an advantage for conservation, but it would still be worth formally recognising the OUV of karst when it exists. To amend a nomination by adding a new criterion after inscription would require the State Party to expend more resources that might be better used elsewhere, but IUCN could better address this issue by helping to identify possibly unrecognised OUV at the pre-nomination stage.

Theme 7:
Coastal systems

Kyung Sik Woo

Figure 19: Fraser Island (Australia). Fraser Island is the largest sand island in the world. The combination of shifting sand-dunes, tropical rainforests and lakes makes it an exceptional property. © IUCN/ Célia Zwahlen

What does the theme cover?

Coastal systems refer to physical processes and physiographical features present in the coastal zone. The coastal zone is the boundary between land and sea, a highly dynamic interface between geological and oceanographical features and including atmospheric (weather and climate) processes and how these are affected by land and sea (Abdulla et al., 2013). But the interface - the shoreline - is mobile, because land can be uplifted or subside, and sea level can rise or fall. Hence coastal landscapes, landforms and sediments develop along a moving interface between land and sea, as well as over long periods of time. The zone over which this interaction plays out can be kilometres wide, and so landforms produced by coastal processes can be found well inland, well above sea level, kilometres offshore and well below present sea level. In many places, coastal landforms are also influenced by ancient antecedent topography. The operation of physical processes in coastal environments is explained by Woodroffe et al., (2011) and Bird (2004), provides a geomorphological classification of coastal landscapes.

Coastal processes were classified into 13 categories in the 2005 report. It stated that coastal processes can display "significant on-going geological processes in the development of landforms" and "significant geomorphological or physiographical features" for criterion (viii). Coastal processes have also been classified worldwide into 62 coastal provinces (from the coastline to 200 m depth) (Spalding, 2012; UNESCO, 2016).

Waves, tides and wind dominate coastal processes and rivers deliver sediment to the coast. These activities lead to the development of coastal landforms that vary according to whether processes play out on hard, rocky coasts or on relatively soft, mobile, sand and gravel coasts. So on the one hand we find cliffs, headlands, reefs, coral lagoons and blue-holes, rias and fjords, while on the other we see beaches, dunes, sand spits and barriers, dune lakes, tidal-flats, deltas and estuaries. Marine canyons may also extend offshore, sometimes for hundreds of kilometres. The coast also supports rich ecosystems, including salt marshes, mangroves, seagrass, coral reefs and salt-tolerant coastal forests and shrub fields.

Due to rapid sea-level rise since the last glaciation, drowned coasts (characterised by rias, fjords and estuaries) are very

Table 7: World Heritage Properties inscribed under criterion (viii) with Theme 7 as the major theme for inscription, or as an ancillary theme.

Criterion (viii) Properties Inscribed Principally Under Theme 7	Date Inscribed (extension)	Criterion (viii) Properties for which Theme 7 was an Ancillary Theme for Inscription	Date inscribed (extension)
Everglades National Park, United States of America	1979	Galápagos Islands, Ecuador	1978 (2001)
Gulf of Porto: Calanche of Piana, Gulf of Girolata, Scandola Reserve, France	1983	Great Barrier Reef, Australia	1981
Fraser Island, Australia	1992	Shark Bay, Western Australia, Australia	1991
Wadden Sea, Denmark, Germany, Netherlands	2009 (2014)	Ha Long Bay, Viet Nam	1994 (2000)
		Desembarco del Granma National Park, Cuba	1999
		Dorset and East Devon Coast, United Kingdom of Great Britain and Northern Ireland	2001

common around the world. Post-glacial sea level stabilised close to its present position about 6,000 years ago. Since that time sea level has varied by less than two metres, depending on location, but sometimes the migration of shoreline position is also driven by on-going tectonics. Thus in some places sea level has the illusion of falling because the land is rising. This can result in a staircase of marine terraces as in the Desembarco del Granma National Park (Cuba). In other places, such as glaciated parts of northern continents, shoreline regression (retreat) is driven by recovery of the land after being depressed under the weight of enormously thick ice sheets. Elsewhere, huge amounts of sediment deposition by large rivers may cause the land to subside and the sea to transgress, thus giving the impression that sea level is rising.

Carbonate coasts and sediments tend to increase towards the tropics but can be constrained by large inputs of muddy sediment. In carbonate-dominated coasts, a clear distinction can be made between tropical to subtropical coral reef-dominated systems and temperate carbonate shell-sand systems. Carbonate beaches and tidal flats are especially found in low latitude regions, where they tend to be controlled by carbonate production rates of shallow marine organisms as well as by physical hydraulic energy. Broad tidal flats composed of carbonates (called sabkha) are present in arid coastal areas. Stromatolites (calcareous microbial growths) are another significant feature of low latitude carbonate coasts (Shark Bay, Western Australia (Australia)).

Where clastic sediments are dominant, different types of coastal landforms can develop according to the balance between tidal and wave energy. Wave-dominated coasts are represented by beach, barrier island and lagoon systems. Tidal flats develop along more sheltered low energy coasts with abundant terrestrial sediment supply. Coastal deltas and deltaic plains also form where rivers discharge abundant sediment.

Many coastal features may be assessed as having OUV due to the great variety of interacting processes involved in their formation and the wide array of hard and soft coast landforms that result. The coastal zone is also affected by the discharge of rivers, and thereby may be influenced by phenomena that may occur thousands of kilometres inland, away from the coastal zone itself (e.g. Everglades National Park (United States of America)). Finally, by virtue of the concentration of human populations in the coastal zone, as well as in the basins of many rivers, coastal zones are among the most threatened globally, human impact affecting the integrity of many coastal features, although in some places there may be sustainable relationships between geodiversity, biodiversity and associated cultural activities.

What had been listed as World Heritage by 2005?

Using the themes recognised in this report, three properties with coastal zone OUV were inscribed on the World Heritage List by 2005, with another six properties that exhibit coastal processes as an ancillary theme (Table 7; Annex 1).

What has been listed as World Heritage since 2005?

The only property listed under this theme since 2005 is the Wadden Sea (Denmark, Germany and Netherlands), which was inscribed on the World Heritage List in 2009 and extended in 2014. This property demonstrates geological and geomorphological components of barrier islands, beaches, tidal flats and ongoing coastal processes, which are strongly associated with the paths of migratory birds between Eurasia and Africa.

Is the thematic advice we have at present sufficient for this theme?

Considering that only one property has been inscribed under this theme since 2005, it can be concluded that the 2005 report was not very effective in stimulating the World Heritage nomination of coastal systems, which, as a result, remain poorly represented on the World Heritage List in terms of recognition under criterion (viii).

Abdulla et al. (2013), provided a global analysis of marine World Heritage Properties for all natural criteria. They identified and mapped 27 coastal and 24 pelagic provinces, representing over 50% of all provinces. Around 44% (27) of all 62 coastal provinces and 65% (24) of all 37 pelagic provinces are completely unrepresented (0 properties) on the World Heritage List. For another 31% (19) of coastal provinces and 30%

Figure 20: Wadden Sea (Denmark, Germany and Netherlands). The largest unbroken system of intertidal sand and mud flats in the world. © IUCN/ Wendy Strahm

(11) of pelagic provinces it is likely that the small area (<1%) covered by existing World Heritage Properties is not adequate to include all features of potential OUV in the province. They suggested that the properties and dynamics of seawater and the ocean itself can represent the OUV. Apart from ecosystem processes specific to coastal and marine systems in criterion (ix), and references to coastal and marine geological processes and themes in criterion (viii), the physical and chemical nature of seawater and ocean water bodies have not been considered, and these are fundamental to the biological processes and species that are the subject of criteria (ix) and (x) (Abdulla et al., 2013).

How well is the theme now represented on the World Heritage List, including its geographical distribution?

The geographical distribution of existing coastal system World Heritage Properties inadequately reflects the widespread occurrence of coastal properties of global importance. There is no case of a 'coastal system' that is fully or over-represented. Evidently, as with some other themes (such as Theme 6) there are many properties located in coastal areas that are included on the World Heritage List under criteria other than criterion (viii). It has been beyond the scope of the present study to undertake an analysis of that coverage (and the extent to which outstanding coastal geoheritage is covered in such properties). The need to provide updated thematic advice in this area should also consider this aspect of the recognition of coastal systems of OUV under criterion (viii).

Any key issues (things to avoid, lessons learned, considerations like serial properties, relevance to other criteria, any 'big stories' missing, key properties for this theme that would meet criterion (viii) that are listed under other criteria, interplay with biodiversity, culture)?

The prevailing 'big story' to be addressed is sea level rise associated with climatic change. Sea level change is a natural process that has been going on for billions of years, but the current particularly rapid rate of rise is exacerbated by human activity via the warming effect of greenhouse gases. So, there is scope for selecting some further World Heritage Properties that contain clear evidence for sea level change and demonstrate the consequences of such changes, whether natural or human-induced. One of the clearest and scientifically most well-known sites from which the history of Quaternary sea level change has been revealed is found in a series of uplifted coral reefs in Papua New Guinea, a Tentative List property referred to as 'Huon Terraces – Stairway to the Past'. Climate change is also associated with a greater incidence of extreme storm events, and these are often particularly manifest along the coast where geological evidence may be left that shows the nature and magnitude of the event (e.g. cyclones), which may be disastrous from a human perspective. Strong physical sedimentary records of both sediments and rocks can be displayed as tempestites, tsunamiites and rhodoid deposits in coast zones. These records help in understanding the geological history (magnitude and frequency) of natural disasters.

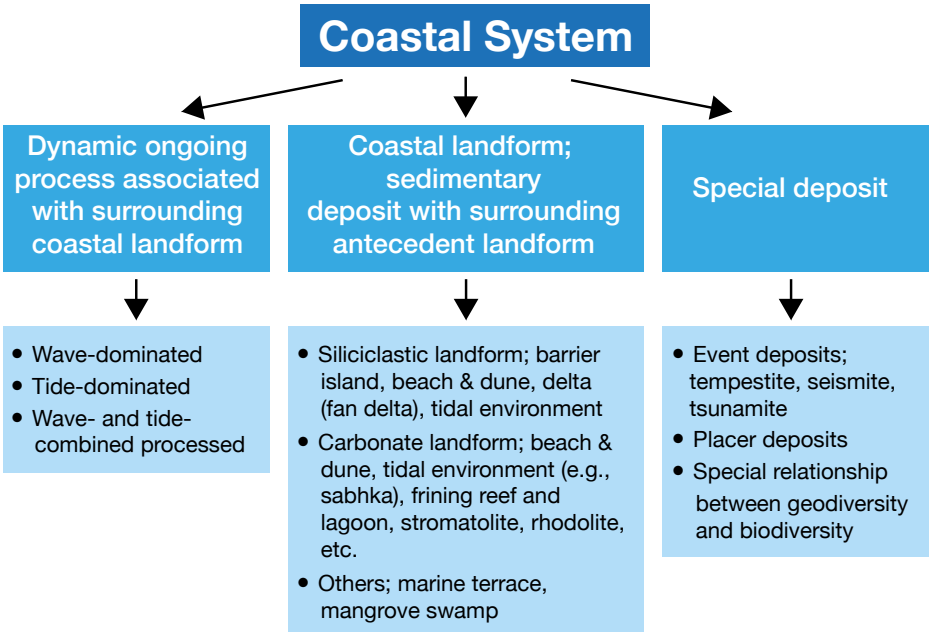


Figure 21: Coastal Classification. © Kyung Sik Woo

Unlike most other geological properties under different themes, coastal (also marine) systems cannot be physically separated from adjacent areas because strong process connections are present due to the combined effects of climate, waves, tide and fluvial discharge. Also, human activities (coastal protection, aquaculture and fisheries) are heavily involved in most areas, and traditional fisheries have sometimes become part of geological and ecological systems in coastal regions. This kind of human involvement in the coastal zone has already been recognised by Abdulla et al. (2013). In many coastal zones, there are areas where geodiversity underpins biodiversity, because organisms living or visiting the coastal zone are dependent upon the food resources in the substrates that are directly associated with geological and oceanographical processes.

Theme 8:
Marine systems

Tom Casadevall, Tove Damholt and Kyung Sik Woo

Figure 22: Great Barrier Reef (Australia). The Great Barrier Reef (GBR) forms the world's largest coral reef ecosystem, ranging from inshore fringing reefs to mid-shelf reefs, and exposed outer reefs, including examples of all stages of reef development. The processes of geological and geomorphological evolution are well represented, linking continental islands, coral cays and reefs. The varied seascapes and landscapes that occur today have been moulded by changing climates and sea levels, and the erosive power of wind and water, over long time periods. One-third of the GBR lies beyond the seaward edge of the shallower reefs; this area comprises continental slope and deep oceanic waters and abyssal plains. © Wise Hok Wai Lum. Source: Wikimedia Commons

What does the theme cover?

Marine systems includes seafloor and submarine features, coral islands, reefs and oceanic islands. The theme encompasses "significant on-going geological processes in the development of landforms, or significant geomorphological features" found in the shallow and deep marine areas.

This theme comprises the former Theme 9 of the 2005 report: 'Reefs, atolls and oceanic islands', but additionally includes the wide range of ongoing processes and geological features of marine areas including physical, chemical and biological processes, tectonic settings and sedimentary environments including continental shelf and slope, basin floors, abyssal plains, oceanic trenches, submarine ridges.

Marine areas cover 70% of the Earth surface, most of which is in deep marine areas. In recent years, there have been a number of advances in the study of the submarine environment including extensive mapping of the seafloor, which has produced a plethora of new information on the marine systems in the deep marine areas.

The theme of Marine systems will have some overlap with other themes such as 'Tectonic systems' e.g. oceanic ridges and/or the theme of 'Volcanic systems' e.g. volcanic islands as well as the theme of 'River, lake and delta systems' and/or 'Coastal systems'.

What had been listed as World Heritage by 2005?

Marine systems were not defined in the 2005 report and only the Great Barrier Reef (Australia) and the Galápagos Islands (Ecuador) were listed with primary features under the then theme of 'Reefs, atolls and oceanic islands'. Shark Bay, Western Australia (Australia) was inscribed in 1991 and recognised especially for its stromatolites under criterion (viii).

What has been listed as World Heritage since 2005?

No properties that use Theme 8 as a primary theme have been inscribed since 2005. Papahānaumokuākea in the mid-Pacific Ocean addresses Theme 8 as an ancillary theme (Table 8; Annex 1), and the fossil Triassic reefs and atolls of The Dolomites (Italy) are listed as ancillary values under Theme 1.

Table 8: World Heritage Properties inscribed under criterion (viii) with Theme 8 as the major theme for inscription, or as an ancillary theme.

Criterion (viii) Properties Inscribed Principally Under Theme 8	Date Inscribed (extension)	Criterion (viii) Properties for which Theme 8 was an Ancillary Theme for Inscription	Date inscribed (extension)
Great Barrier Reef, Australia	1981	Galápagos Islands, Ecuador	1978 (2001)
		Papahānaumokuākea, United States of America	2010

Evidently a number of atolls and reefs are inscribed under other natural criteria than criterion (viii) and a full evaluation of the representation of these features on the World Heritage List would have to take this into consideration, important amongst these is the Ningaloo Coast (Australia), inscribed under criteria (vii) and (x) but having one of the world's longest near-shore coral reefs. All other marine features than oceanic islands, atolls and reefs are apparently very poorly represented or missing indicating a substantial gap in the representation of marine features on the World Heritage List.

Is the thematic advice we have at present sufficient for this theme?

While this is a newly defined theme, given that only one inscription was made since 2005 that falls under the former theme of 'Reefs, atolls and oceanic islands', it is clear that the 2005 report did not provide the stimulus to States Parties, in relation to the application of criterion (viii).

As noted in the previous Theme (Coastal systems), Abdulla et al. (2013) remains an important broader thematic reference for the listing of marine World Heritage. There appears to be a need to provide further specific guidance on the positioning of criterion (viii) in relation to the current and future recognition of marine World Heritage.

How well is the theme now represented on the World Heritage List, including its geographical distribution?

Given the small number of criterion (viii) World Heritage Properties currently listed in relation to the Marine systems theme, it is difficult to assess the question of equitable geographical distribution. Some notable marine environments such as the Indian Ocean, the Polar Regions and most of the Atlantic Ocean currently lack any properties inscribed under criterion (viii) on the World Heritage List, however, the extent of coverage by properties listed under other themes needs to be considered in assessing representation.

Any key issues (things to avoid, lessons learned, considerations like serial properties, relevance to other criteria, any 'big stories' missing, key properties for this theme that would meet criterion (viii) that are listed under other criteria, interplay with biodiversity, culture)?

As this is a newly defined theme and as most of the deep marine environments have not been included previously on the World Heritage List, it is reasonable to say that many of the 'big stories' of the geoheritage of Marine systems remain to be revealed within the World Heritage List.

There are likely to be number of missing elements under criterion (viii) related to most of the overall features included in the theme. Features recommended by Abdulla et al. (2013), complemented by biogenic features to include the atolls and reefs are as follows:

- plates and tectonic features;
- hotspot, seamounts;
- vents, seeps and other hydrogeological features;
- sedimentary processes (clastic processes and products);
- biogenic features (atolls, reefs, etc.).

As the scope of the present report does not allow for a thorough study on the means to respond to the 'big stories', it is recommended that a thematic study and gap analysis for the theme of Marine systems under criterion (viii) be undertaken to identify the missing elements for future listings. In considering such a study, including the recommendations of Abdulla et al. (2013), it is important to note that some of these aspects can also be taken forward in relation to the application of other themes (for instance see the discussion of marine volcanism in Theme 4).

One example of a 'big story' that is at present only touched on in a limited and incomplete fashion is the submarine expression of plate tectonic boundaries – spreading centres, subduction zones and expressions of hot spots. One could envision for example a serial property nomination to encompass key elements of the Mid-Atlantic Rift system, which collectively would tell the story of this major Earth tectonic feature (but noting the link to implementation of Themes 2 and 4). Another topic missing on the World Heritage List is the marine sedimentary systems of canyons, channels and submarine fans telling the story of on-going processes acting at giant scale in the deep marine.

The importance of including marine natural heritage on the World Heritage List has been recognised in a number of recent reports from IUCN (Abdulla et al., 2013; Freestone et al., 2016; Casadevall et al., 2019). As noted in these reports, a key issue relates to who has jurisdiction to propose, manage and protect areas of the deep marine environment. These environments cover half of the Earth's surface, most of which lies beyond the jurisdiction of nations. However, and as mentioned under the 'Volcanic systems' theme, the plethora of recent deep sea floor mapping and exploration has revealed a variety of seafloor features and environments, which may merit protection from threats due to mineral resource exploitation, disposal of wastes from human activity such as mining, dredging for seafoods etc. This represents a further reason to explore the extension of the application of the World Heritage Convention to the High Seas.

Theme 9:
Glacial and periglacial systems

Lovísa Ásbjörnsdóttir

Figure 23: Ilulissat Icefjord (Denmark). The Ilulissat Icefjord is an outstanding example of a stage in the Earth's history: the last ice age of the Quaternary Period. The ice-stream is one of the fastest (40 m per day) and most active in the world. Its annual calving of over 46 km^3 of ice accounts for 10% of the production of all Greenland calf ice, more than any other glacier outside Antarctica. The property has significantly added to the understanding of ice-cap glaciology, climate change and related geomorphic processes. © Ko Hon Chiu Vincent. Source: UNESCO

What does the theme cover?

This theme includes geological processes, landscape and geomorphological features developed by past or present glacial and periglacial systems. Theme 9 is equivalent to the former two themes, 10 'Glaciers and ice caps' and 11 'Ice Ages', described in the 2005 report. The new theme, Theme 9, includes 17% of the World Heritage Properties inscribed under criterion (viii) for their OUV (primary elements).

Glacier and glacial landscapes are often described as being of the most outstanding and spectacular natural beauty and several World Heritage Properties have been inscribed under criterion (vii), for example, Mount Kenya National Park/ Natural Forest (Kenya), Sagarmatha National Park (Nepal) and Waterton Glacier International Peace Park (Canada and United States of America). The glacial landscape represents diverse glacial landforms and geomorphic or physiographic features, both at a large and small scale, created by glacial processes such as erosion and deposition. Present day glaciers and ice caps are mainly found in high northern and southern latitudes and in high mountain ranges. Their existence is dependent upon a cold climate and precipitation. The glaciers mass balance, being the difference between accumulation of snow in the winter and ablation of ice during summer, are recorded globally and used as an indication of climate change.

Glaciers are in broad sense classified into two main types, warm-based or temperate glaciers and cold-based or polar glaciers, but in between are variations of intermediate thermal glaciers, for example sub-polar glaciers. The thermal condition of the glaciers together with ice thickness and gravity due to sub-glacial topography and type of bedrock are one of the factors that affects their dynamics and simultaneously the magnitude of erosion and carving. There are several different types of glaciers. Large continental masses of glacial ice are called ice sheets, such as those covering Antarctica and Greenland. Ice caps are smaller, usually less than 50,000 square kilometres and are mainly found in polar and sub-polar regions, e.g. Vatnajökull National Park - Dynamic Nature of Fire and Ice (Iceland). Mountain glaciers develop in high mountains regions and include smaller cirque glaciers in bowl-shaped eroded landforms. Valley glaciers and outlet glaciers are the

Table 9: World Heritage Properties inscribed under criterion (viii) with Theme 9 as the major theme for inscription, or as an ancillary theme.

Criterion (viii) Properties Inscribed Principally Under Theme 9	Date Inscribed (extension)	Criterion (viii) Properties for which Theme 9 was an Ancillary Theme for Inscription	Date inscribed (extension)
Kluane / Wrangell-St. Elias / Glacier Bay / Tatshenshini-Alsek, Canada and United States of America	1979 (1992, 1994)	Gros Morne National Park, Canada	1987
Los Glaciares National Park, Argentina	1981	Heard and McDonald Islands, Australia	1997
Tasmanian Wilderness, Australia	1982 (1989)		
Pirin National Park, Bulgaria	1983 (2010)		
Talamanca Range-La Amistad Reserves / La Amistad National Park, Costa Rica, Panama	1983 (1990)		
Yosemite National Park, United States of America	1984		
Huascarán National Park, Peru	1985		
Te Wahipounamu – South West New Zealand, New Zealand	1990		
Laponian Area, Sweden	1996		
Pyrénées - Mont Perdu, France, Spain	1997 (1999)		
High Coast / Kvarken Archipelago, Finland, Sweden	2000 (2006)		
Swiss Alps Jungfrau-Aletsch, Switzerland	2001 (2007)		
Ilulissat Icefjord, Denmark	2004		
West Norwegian Fjords – Geirangerfjord and Nærøyfjord, Norway	2005		
Tajik National Park (Mountains of the Pamirs), Tajikistan	2013		
Vatnajökull National Park - Dynamic Nature of Fire and Ice, Iceland	2019		

flowing or streaming part of mountain glaciers or ice caps. They become piedmont glaciers when they spread out entering flat land but are called tidewater glaciers when reaching out into the sea. Rock glaciers are slow moving glaciers, with variable amounts of ice involved, which are covered with rock and debris preventing the ice from melting.

Diverse glacial landforms and glacial landscapes are created by erosional and depositional processes in different glacial environments. The main environments are glacial, glacio-fluvial, glacio-lacustrine and glacio-marine. In glacial environments, older glacial landforms and features are often eroded or covered by younger glacial erosion and deposits.

Periglacial systems are found in cold climate regions where permafrost and freeze-thaw processes are the dominant factors effecting the environment. These processes develop characteristic and diverse landform in periglacial environments, for example patterned ground, palsas and pingos. Permafrost is defined as a ground material (soil, rock, ice, or organic material) that remains at or below 0°C for at least two consecutive years. Its main characteristic is the permanently frozen conditions of ground water and vapour within the sediments and bedrocks affected by the cold climate. At the surface is the active layer often about one metre thick that seasonally and repeatedly freezes and thaws. Permafrost exists in large areas of non-glacial environments in the polar regions, but it also occurs (to a lesser extent) as mountain permafrost in many of the higher mountain areas in the world and as subsea permafrost in the continental shelves of the Arctic Ocean. Global warming in the past decades has caused changes in the glacial and periglacial environments and is an on-going condition which may have unforeseen consequences in the future.

The description for the theme 'Ice Ages' in the 2005 report is good and valid. It includes global patterns of continental icesheet expansion and recession, isostasy, sea-level changes and associated biogeographic records.

The major Ice Ages in the Earth's history are:

- The Huronian (2.4-2.1 billion years ago);
- The Cryogenian (720-635 million years ago);
- The Early Palaeozoic (460-420 million years ago), the Andean-Saharan Ice Age;

Figure 24: Los Glaciares National Park (Argentina). Significant process of glaciation, as well as of geological, geomorphological and physiographical phenomena caused by the ongoing advance and retreat of the glaciations that took place during the Pleistocene epoch in the Quaternary period, and the neoglaciations corresponding to the current epoch or Holocene. © Philipp Schinz. Source: UNESCO

- The Late Palaeozoic (360-260 million years ago), the Karoo Ice Age;
- The Cenozoic (2.8 million-10,000 years ago), the Quaternary Ice Age.

The Quaternary Ice Age is a rather well-documented event in the Earth's history, especially in the Northern Hemisphere but that is not the case with the older Ice Ages. However, geological records of glacial deposits and erosion, relative sea level changes, fossil records and chemical elements are evidence of colder climate condition effecting the palaeoenvironment long before the last Ice Age.

What had been listed as World Heritage by 2005?

By 2005, 14 properties had been inscribed on the World Heritage List under Theme 9 and two additional properties inscribed with ancillary elements under this theme (Table 9; Annex 1). The 14 properties are divided between sites with present glaciers and active glacial processes and sites without glaciers but including glacial landscapes and features from the Pleistocene Epoch. Only one property under Theme 9, Laponian Area (Sweden), mention the periglacial processes of freeze-thaw.

What has been listed as World Heritage since 2005?

Since 2005, two properties have been inscribed solely or jointly with other themes: 1) Tajik National Park (Mountains of the Pamirs), (Tajikistan), which is at the centre of glaciation on the Eurasian continent and 2) Vatnajökull National Park (Iceland) for the 'dynamic nature of fire and ice', with OUV for two Themes, 9 and 4.

Is the thematic advice we have at present sufficient for this theme?

In the 2005 report, the thematic advice provides clarity on the elements of criterion (viii) were divided into four parts and defined with a list of processes, landforms and features recognised within each part. The two themes at the time ('Glaciers and ice caps' and 'Ice Ages') was clearly described. The reason that only two inscriptions have been assigned for Theme 9 since 2005 can partly be explained by the relatively high number of inscriptions related to this theme before 2005. A number of potentially relevant properties were also inscribed under criterion (vii). A recent inventory of glaciers inside World Heritage Properties, independent of criteria inscriptions, gave the result of 46 properties with notable glaciers within their boundaries (Bosson et al., 2019). In 2020, at least seven sites on the Tentative Lists of States Parties are described as being glacial and periglacial systems.

How well is the theme now represented on the World Heritage List, including its geographical distribution?

Theme 9 is relatively well represented, but with an uneven geographical distribution Europe and North America (11 properties), Asia and Pacific (four properties) and Latin America and the Caribbean (three properties). The theme has not yet

been used for inscription of properties in the Arab States and Africa, but this reflects the geography of the planet

Periglacial systems are under-represented on the World Heritage List even though permafrost regions extend over 25% of the Earth's terrestrial areas. Large permafrost areas exist in northern Canada, Alaska (USA), Russian Federation and China. Periglacial system are in properties inscribed under others themes, for example Lena Pillars Nature Park (Russian Federation) and are also found in World Heritage Properties inscribed for criterion (vii) and biodiversity, e.g. Putorana Plateau (Russian Federation).

Any key issues (things to avoid, lessons learned, considerations like serial properties, relevance to other criteria, any 'big stories' missing, key properties for this theme that would meet criterion (viii) that are listed under other criteria, interplay with biodiversity, culture)?

The key issue for Theme 9 is the changing climate globally. In the past decade, we have witnessed that glaciers are retreating fast, and periglacial areas are thawing. Bosson et al. (2019) provides an inventory, based on the newest available data on glaciers in 2017, and glacier evolution modelling for 46 World Heritage glaciers sites. The results predict that by the year 2100, more than 80% of the ice volume of glaciers in 2017 is expected to have melted in 20 or 41 sites according to the models low or high emission scenario. Glacier 'extinction' or disappearance is forecasted in eight to 21 World Heritage Properties. In the research, it is also pointed out that this decline in World Heritage glaciers will strongly affect the integrity and value of many of these sites and can even be a threat to their OUV.

The 'big stories' of the major Ice Ages in Earth's history are their causes and effects. Does the rock record hold any evidence of the likely causes of these Ice Ages? How are these Ice Ages represented in geological formations and erosions? How do they represent changes in palaeoclimates, palaeoenvironments, atmospheric composition, changes in tectonic or changes in the fossil record? It is clear that inscription of older Ice Ages can be complex and it will have a strong interplay with other themes. To cover some of these topics, inscription as a serial or transboundary properties could be considered.

Theme 9 has the characteristic of interacting with many other themes under criterion (viii) and with other criteria as well. Glacial and periglacial systems are common under criterion (vii), but are also found under criteria (ix) and (x) as the theme creates a foundation for a specific ecological environment, biological diversity and habitats.

Multibeam surveys of the sea floor have revealed glacial landforms that provide additional information on terrestrial glaciation. It is not unlikely that in the near future a new technology will reveal geological properties of OUV for Theme 9 and other themes of criterion (viii).

Theme 10:
Desert and semi-desert systems

Piotr Migoń

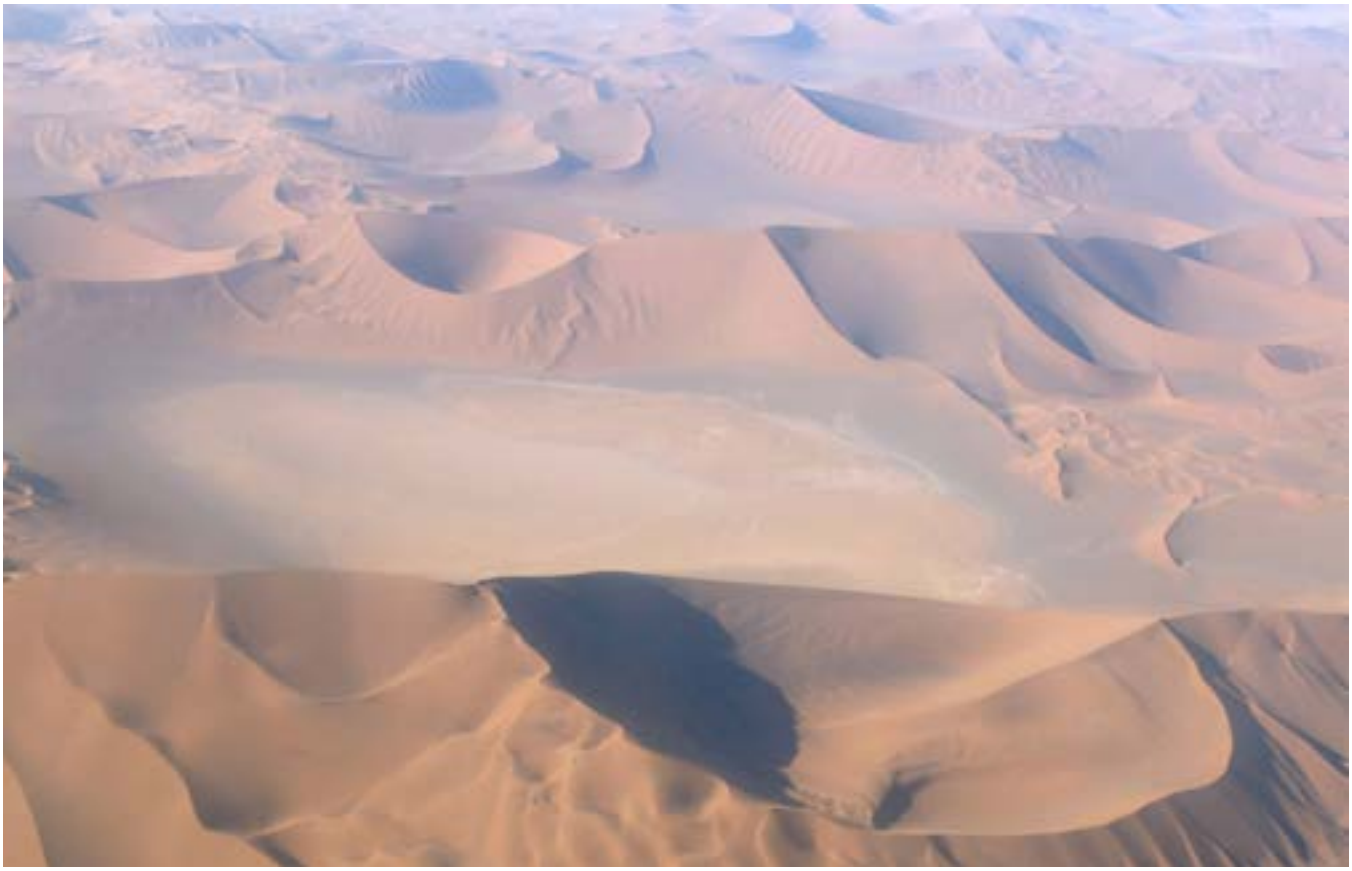


Figure 25: Lut Desert (Iran). The Lut Desert is a classic locality of yardangs developed on a massive scale, as well as gravel plains and dune fields. © Paul Williams

What does the theme cover?

The theme Desert and semi-desert systems is presented in the 2005 report as 'Arid and semi-arid desert systems' and emphasises specific environments rather than a particular surface process or group of processes. However, in order to minimise overlaps within the present framework and to make it as clear as possible, this category is understood as primarily designed to cover aeolian processes and landforms, as well as features produced by intermittent runoff and evaporation. Thus, it includes landscape features such as dunes and dune fields of various types and sizes, yardangs, deflation hollows, wadis and playas.

What had been listed as World Heritage by 2005?

The 2005 report mentioned that four properties had OUV under this 'Arid and semi-arid desert systems' theme (Willandra Lakes Region (Australia), Tassili n'Ajjer (Algeria), Uluru-Kata Tjuta National Park (Australia) and Purnululu National Park (Australia), but none had actually been inscribed under that theme (Table 10; Annex 1).

What has been listed as World Heritage since 2005?

The current representation of desert and semi-desert systems among World Heritage Properties, inscribed under criterion (viii) is very limited. There are only three such properties, all inscribed after the 2005 report:

- El Pinacate and Gran Desierto de Altar Biosphere Reserve (Mexico) – includes part of the Sonoran Desert, with star dunes and linear dunes of considerable height. This property also includes significant volcanic features.
- Namib Sand Sea (Namibia) – hosts diverse dune landscapes, representing an almost complete catalogue of dune types (star, linear, transverse, barchans), as well as other desert surface features such as interdune corridors, gravel plains, ephemeral channels and playas.
- Lut Desert (Iran) – includes classic locality of yardangs developed on a massive scale, as well as gravel plains and dune fields.

There are several additional World Heritage Properties relevant to the theme, but inscribed under criteria other than criterion (viii). However, justifications of inscription show that landscape features produced by desert environmental processes were considered crucial for the OUV of these properties. These are:

1. Air and Ténéré Natural Reserves (Niger), (vii), (ix) and (x) – include dune fields surrounding residual volcanic massifs in the hyper-arid environment.

Table 10: World Heritage Properties inscribed under criterion (viii) with Theme 10 as the major theme for inscription, or as an ancillary theme.

Criterion (viii) Properties Inscribed Principally Under Theme 10	Date Inscribed (extension)	Criterion (viii) Properties for which Theme 10 was an Ancillary Theme for Inscription	Date inscribed (extension)
El Pinacate and Gran Desierto de Altar Biosphere Reserve, Mexico	2013		
Namib Sand Sea, Namibia	2013		
Lut Desert, Iran	2016		

2. Lakes of Ounianga (Chad), (vii) – a group of lakes within an otherwise hyper-arid environment, fed by groundwater and surrounded by dunes and desert pavements, filling surface depressions formed by aeolian erosion (deflation).
3. Okavango Delta (Botswana), (vii), (ix) and (x) – overlapping with Theme 5 (River, lake and delta systems), it also represents geomorphic features resulting from specific hydrological functioning of drylands, with considerable seasonal variations in runoff.

Furthermore, as with other themes, there are many more properties included on the World Heritage List within arid and semi-arid environments but listed for values not related to desert geomorphology (such as Wadi Al-Hitan (Whale Valley), (Egypt), which is listed for its spectacular fossils, but in a diverse natural desert landscape.

Is the thematic advice we have at present sufficient for this theme?

Desert and semi-desert systems have been the subject of a thematic study commissioned by IUCN (Goudie & Seely, 2011). This study comprehensively covered desert environments, identifying various geomorphological features present in the world's deserts, whether directly formed by dry climate processes or not, but also indicating three unique subjects for drylands: (a) wind processes and landforms, (b) weathering processes, forms and surface materials, specifically different types of near-surface crusts, and (c) fossil lakes and other pluvial evidence. The latter is particularly important in the context of climate change over geological timescales, providing evidence of drastic shifts in climate, especially during the Quaternary. It needs to be noted that five out of the six World Heritage Properties listed above were inscribed after the thematic study was published, although work towards their nominations may have started earlier.

Goudie & Seely (2011) also noted several World Heritage Properties located in deserts which contain representative desert surface features, although not of OUV and inscribed under different natural and cultural criteria. Among them, properties inscribed in recognition of rock art are particularly relevant, as this rock art often provides evidence of drastic climate change experienced in recent Earth history. They also found several properties on the Tentative List, which illustrate desert processes, with a few having been inscribed in the following years.

This 2011 thematic advice remains relevant and effective as a basis for guiding future application of criterion (viii) under this theme.

How well is the theme now represented on the World Heritage List, including its geographical distribution?

The current representation of desert and semi-desert systems is relatively modest, although the actual number of properties located in arid and semi-arid areas is much higher. Many, however, were inscribed as outstanding examples of erosional systems and palaeontological properties, as well as for rock art (as Cultural World Heritage), rather than for aeolian or other specifically dry climate processes. Among the six properties listed above, four are located in Africa whereas Asia and North America are represented by one property each. This low number stands in stark contrast to the area covered by world's deserts and semi-deserts, estimated by Goudie & Seely (2011) for one third of the total continental area. Evident geographical gaps are deserts of Middle East, Central and East Asia, Australia, as well as the semi-desert areas of South America. The vastness of the Sahara and the diversity of the North American drylands also offers potential for identification of further features of OUV.

Any key issues (things to avoid, lessons learned, considerations like serial properties, relevance to other criteria, any 'big stories' missing, key properties for this theme that would meet criterion (viii) that are listed under other criteria, interplay with biodiversity, culture)?

In terms of diversity of desert processes and landforms, the majority of properties illustrate depositional effects of aeolian processes, being focused on dune landscapes. Star and linear dunes are highlighted, whereas other dunes types such as transverse dune fields and barchans are less exposed. Effects of aeolian erosion (deflation) are emphasised in one case only (Lut Desert (Iran)) and there is the scope for further investigation and nominations. Desert lakes and playas (former lake basins, including seasonal lakes), whether in inland or coastal locations (sabkhas), are clearly under-represented. Another gap is complex desert geomorphological systems, which would explicitly integrate erosional, transitional and depositional features into one system, addressing the condition of integrity. Two variants may be distinguished here: (a) aeolian systems, from deflation surfaces (playas, stony deserts, wind-moulded bedrock outcrops) to dune fields; (b) runoff-evaporation systems, from channel networks in the higher ground to seasonal lakes and playas. The theme of desert landscapes as evidence of climate change is definitely worth exploration, both for existing properties (including those inscribed under cultural criteria) and potential properties. It may be linked with cultural World Heritage

Figure 26: Namib Sand Sea (Namibia). This property hosts diverse dune landscapes, representing an almost complete catalogue of dune types (star, linear, transverse, barchans), as well as other desert surface features such as interdune corridors, gravel plains, ephemeral channels and playas. © Ko Hon Chiu Vincent. Source: UNESCO

as the sensitivity of dry environments to climate change often contributed to rises and falls of ancient civilisations, which have left tangible evidence (abandoned settlements, relict cultural landscapes). Rapidly increasing literature on this subject will provide solid scientific background for further action.

In the dual context of desert and semi-desert systems and climate change, a theme of loess deposits (wind-blown silt) is identified as completely missing from the World Heritage List. Loess, with associated palaeosols (buried soils) is an important carrier of palaeoenvironmental information, which in suitable settings covers the entire Quaternary Period, providing a unique terrestrial record of climate change. The thickness of continuous loess may exceed 100 m and is often well exposed. In certain localities loess is linked with distinctive features of surface erosion (gully networks, escarpments), illustrating on-going geological (geomorphological) processes and significant geomorphic formations. Supporting fertile soils, loess areas have been inhabited and turned into agricultural land early in the human history. As a consequence, they are rich in archaeological evidence, often of unique value. The potential of loess deposits and landscapes may be explored in East and Central Asia, Central and Eastern Europe in particular, but loess deposits occur on all continents.

Thus, whilst the specific guidance for the application of criterion (viii) remains relevant, it may be that deserts would benefit from a greater connection of the recognition of geoheritage to the wider recognition of cultural and natural World Heritage.

Theme 11:
Meteorite impacts

Tove Damholt

Figure 27: Vredefort Dome (South Africa). The Vredefort Dome is the oldest, largest and most deeply eroded complex meteorite impact structure in the world and the site of the world's greatest single, known energy release event. © OUR PLACE The World. Source: UNESCO

What does the theme cover?

The theme of Meteorite impacts includes features produced by the impacts of meteors, comets, asteroids and other extra-terrestrial objects with the Earth, including both physical structures formed by extra-terrestrial impacts, such as impact craters, as well as major effects caused by them, such as mass extinction. Impacts by, and accretion of, extra-terrestrial bodies was the fundamental process by which the Earth grew to its current size. It was also a dominant geological process throughout the early history of the Solar System and a variety of possible effects have been ascribed to impacts on Earth including the origin of the Earth's moon, the contribution to the Earth's quantity of volatile gases, and effects on the evolution of early life. In more recent geological time, at least one mass extinction event is linked to global effects caused by a major impact event (e.g. Osinski & Pierazzo, 2012).

Most of the physical structures formed by impacts of extra-terrestrial bodies on Earth have been obliterated by later geological processes and only a few of the more than 190 impact craters[3] that have been identified still display the characteristic crater morphology with an annular depression surrounded by an elevated crater rim.

What had been listed as World Heritage by 2005?

At the time of the publication of the 2005 report, only one property had been inscribed on the World Heritage List under this theme, Vredefort Dome (South Africa), which is the oldest, largest and most deeply eroded complex meteorite impact structure in the world (Table 11; Annex 1). It is the site of the world's greatest single known energy release event and contains high quality and accessible geological (outcrop) properties, which demonstrate a range of geological evidences of a complex meteorite impact structure.

What has been listed as World Heritage since 2005?

In 2014, Stevns Klint (Denmark) was inscribed under this theme. The property bears evidence of the asteroid impact believed to have caused the mass extinction that led to the end of the Age of the Dinosaurs and has iconic scientific importance due to its association with the radical theory for asteroid driven extinction. In 2014, decision 38 COM 8B.10 of the World Heritage Committee followed the recommendation of IUCN and considered "that this nomination can be regarded as completing the recognition of the phenomenon of asteroid impact, and its impact on the history of life on Earth, on the

3 **Earth Impact Database, 2019 -** http://www.passc.net/EarthImpactDatabase/New%20website_05-2018/Index.html

Table 11: World Heritage Properties inscribed under criterion (viii) with Theme 11 as the major theme for inscription, or as an ancillary theme.

Criterion (viii) Properties Inscribed Principally Under Theme 11	Date Inscribed (extension)	Criterion (viii) Properties for which Theme 11 was an Ancillary Theme for Inscription	Date inscribed (extension)
Vredefort Dome, South Africa	2005	Barberton Makhonjwa Mountains, South Africa	2018
Stevns Klint, Demark	2014		

World Heritage List." The Barberton Makhonjwa Mountains (South Africa), an Archean property inscribed under several themes (Theme 1, 2, 4 and 11), contains several thin beds interpreted as meteorite fall-back breccia reflecting the massive bombardments of the early Earth.

Is the thematic advice we have at present sufficient for this theme?

In the 2005 report, the 'Meteorite impact' theme is described as "physical evidence of meteorite impacts (astroblemes), and major changes that have resulted from them, such as extinctions." This led to the nomination and inscription of Stevns Klint (Denmark) in 2014. This theme has not been seen as requiring a separate thematic study.

How well is the theme now represented on the World Heritage List, including its geographical distribution?

As mentioned there are only two properties on the World Heritage List that represent meteorite impacts, one in Africa and one in Europe, plus one property in Africa that contains meteorite fall-back spherules. Further, it should be noted again that following the nomination of the Stevns Klint (Denmark) in 2014, it can be considered that this theme is now fully represented on the World Heritage List regardless of geographical distribution.

Any key issues (things to avoid, lessons learned, considerations like serial properties, relevance to other criteria, any 'big stories' missing, key properties for this theme that would meet criterion (viii) that are listed under other criteria, interplay with biodiversity, culture)?

The theme is well represented considering the more limited scope, compared to the other themes recognised within criterion (viii). This is particularly the case with regards to the very old and very large physical features related to impacts by extra-terrestrial bodies by the eroded crater of Vredefort Dome supplemented by the fall back breccia of the Barberton Makhonjwa Mountains (both in South Africa). Stevns Klint (Denmark) forms an equally strong representation of the effect of an extra-terrestrial impact on the record of life on Earth. It is remarkable, however, that the list does not include the feature that is most spectacular and easily understandable to everyone: a well-preserved impact crater with a clearly visible annular depression surrounded by an elevated crater rim. The 'big stories' of the theme are thus regarded as fully covered except for the representation of a crater structure clearly visible to the untrained eye, and recognised as such to a wide public.

Figure 28: Stevns Klint (Denmark). The Stevns Klint bears evidence of the asteroid impact believed to have caused the mass extinction that led to the end of the Age of the Dinosaurs. It is of iconic scientific importance due to its association with the radical theory for asteroid driven extinction. © Jacob Lautrup. Source: UNESCO

Comparative analysis

Figure 29: Mistaken Point (Canada). These rugged coastal cliffs of deep marine origin date to the middle of the Ediacaran Period 580-560 million years ago. They record 'when life got big', the first abundant appearance of large, biologically complex organisms after three billion years of mainly microbial evolution. © Mistaken Point Ambassadors Inc, Barrett & MacKay Photography. Source: UNESCO

As mentioned previously, apart from justifying OUV, any World Heritage nomination must also include a full and detailed comparative analysis, the definition of boundaries, meet the conditions of integrity and demonstrate adequate long-term protection and management, which should reflect the extent and character of the attributes that convey the OUV. To assist in the assessment of OUV, it is necessary to perform a global comparative analysis with other sites and areas (including those already inscribed on the World Heritage List) across the world that contain or display similar elements. The following three cases are examples of how the building of a comparative analysis was done for recently designated World Heritage Properties nominated under criterion (viii). Collectively, these three examples show some commonalities that extend across all 11 themes in geological World Heritage (Figure 2), including the overarching need to identify a gap in attributes of OUV among all existing World Heritage Properties before beginning the nomination, the utility of creating a formal list of required and desired criteria to permit equal comparisons among all relevant sites worldwide, and the value of a rigorous scoring system to rank individual sites relative to these previously defined criteria. At the same time, these examples also show that some aspects of each theme are unique to that theme and thus require some individuality in the criteria for comparisons. It is recommended to consider these, but also to contact IUCN beforehand, in order to establish an effective comparative analysis methodology.

Theme 1: Mistaken Point, Canada

For the past two decades, all nominations under Theme 1 have used a similar 'best practice' method for the comparative analysis of fossil sites as illustrated by the analysis of Mistaken Point (IUCN, 2016, p. 56-57; Thomas and Narbonne, 2015, p. 59-69). The evaluation started with a comparison of Mistaken Point with all World Heritage fossil sites, none of which contained any part of the OUV proposed for Mistaken Point.

Evaluation of all Ediacaran fossil sites worldwide was aided by comparative work undertaken by two international Ediacaran fossil experts who analysed all 109 sites worldwide where Ediacaran fossils had been reported, identifying 84 sites they regarded as valid, and then further distilling this list to 13 sites

CATEGORY 1 Fossil record of Ediacara-type soft-bodied macrofossil deiversity	1. Number of Ediacara-type macrofossil genera (*sensu lato*) known from the site 2. Higher level diversity 3. Number of Ediacaran macrofossil specimens of 'animal-like character' estimated to be visible and *in situ* at the site 4. Wider evolutionary signifiance
CATEGORY 2 Nature and quality of the fossil archive	5. Quality of preserved Ediacara-type preservation 6. Exposed stratigraphic thickness 7. Geochronological constraints 8. Age of the fossil assemblages 9. Range of major depositional environments represented at the site
CATEGORY 3 Permanence (integrity) and scientific impact of the site	10. Degree of site investigation 11. Ease of access to the site 12. Permanence of the site

Figure 30: Summary of the criteria assessed in the Global Comparative Analysis of Ediacaran fossil properties. Modified from Thomas and Narbonne, 2015, Table 3.2

on five continents with sufficient age certainty and fossil diversity to potentially justify OUV. These 13 sites were then assessed on the basis of 12 criteria reflecting the ten questions on the 'IUCN fossil site evaluation checklist' (Annex 2) that critically assessed the record of fossil diversity at the site, the nature and quality of the fossil archive at the site, and the permanence (integrity) and scientific impact of the site (Figure 30). The 13 short-listed Ediacaran sites were then assessed as objectively as possible under these 12 criteria, typically using numerical subcategories such as stratigraphic thickness, number of fossils described, number of fossil species recognised, and number of scientific papers documenting the site for ranking within each criterion. The short-listed sites were then ranked numerically from 1 to 13 within each criterion, and the results were summed to produce a matrix for global comparative analysis. A final test of the comparative matrix was to critically compare the ranking (both overall and in each specific criterion) of all 13 sites with the Statement of OUV of the nominated site as representing the "outstanding record of a critical milestone in the history of life on Earth, 'when life got big' after almost three billion years of microbe-dominated evolution" (Thomas and Narbonne, 2015, Fig. 3.6).

Theme 4: Vatnajökull National Park - Dynamic Nature of Fire and Ice, Iceland

Volcanic systems have recently received a high degree of attention, with comprehensive global reviews of all inscribed World Heritage Properties that display volcanic features as part of their OUV (Wood, 2009; Casadevall et al., 2019). These reviews have provided excellent summations of the breadth of volcanic features preserved in World Heritage Properties worldwide, but also reveal some significant volcanic features and processes not represented in any World Heritage Property.

The inscription of Iceland's Vatnajökull National Park - Dynamic Nature of Fire and Ice (VPN) property on the World Heritage List in 2019 filled a major gap in the coverage of volcanic systems – the volcanic systems that produce a mid-ocean ridge. Iceland is the only part of the actively spreading Mid-Atlantic Ridge that is above sea level. The comparative analysis for the VPN nomination was with 13 sites, six of them World Heritage Properties plus seven other prominent sites, which have similar tectonic, glacio-volcanic, volcanic and/or glaciological processes. From this comparative analysis, it was clear that VPN stood out as being, by far, the most diverse site in terms of the types of landforms related to volcanism and glacio-volcanism. No property inscribed on the World Heritage List presented active ice dominant glacio-volcanism or glacio-volcanic landforms such as Tuya and Tindar ridges, Móberg (hyaloclastite) formations, jökulhlaup and Sandur or glacial outwash plains. In the comparative analysis, the volcanic fields of Antarctica came close to the VPN in diversity, but they had lower levels of Holocene volcanic activity and many are in areas that are difficult to access (Baldursson et al., 2018).

The IUCN evaluation report for VPN (IUCN, 2019) concluded:

> "The property comprises an entire system where magma and the lithosphere are incessantly interacting with the cryosphere, hydrosphere and atmosphere to create extremely dynamic and diverse geological processes and landforms that are currently underrepresented or not found on the World Heritage List."

Theme 11: Stevns Klint, Denmark

The mass extinction at the Cretaceous-Palaeogene boundary represents the latest, and by far best understood and most publicised, of the five major faunal turnovers (mass extinction events) that punctuated the Phanerozoic history of life on Earth (Raup & Sepkoski, 1982; Fan et al., 2020). It was also the first mass extinction event that was demonstrably related to an extra-terrestrial impact (Alvarez et al., 1980). Recognising that this event was not already represented on the World Heritage List, Stevns Klint was proposed for adoption as representing a 'major stage in Earth's history, including the record of life', thus fulfilling criterion (viii).

Figure 31: Vatnajökull National Park - Dynamic Nature of Fire and Ice (Iceland). This is an iconic volcanic region that also features the continental drifting currently active in this part of Atlantic Ocean with ten central volcanoes, eight of which are subglacial. Two of these are among the most active in Iceland. The interaction between volcanoes and the rifts that underlie the Vatnajökull ice cap takes many forms, the most spectacular of which is the jökulhlaup – a sudden flood caused by the breach of the margin of a glacier. © Þorvarður Árnason. Source: UNESCO

The comparative analysis used an existing database (KTbase) of more than 500 sites marking the Cretaceous–Palaeogene boundary (Damholt & Surlyk, 2012), and was performed in two stages:

First three prerequisites were defined to ensure that all sites examined in further detail comprised the key attributes telling the complete story of the biotic turnover across the Cretaceous–Palaeogene boundary layer and included traces of the extra-terrestrial impact.

Completeness across the boundary, including the latest Cretaceous and the earliest Palaeogene strata in order to represent the entire event, the nature of the mass extinction and the subsequent recovery of life after the extinction.
Well studied and described, allowing comparison.
Boundary layer lithologically different from the underlying Cretaceous sediments and the overlying Palaeogene sediments, **and including the characteristic enrichment** in iridium and other rare elements.

These three criteria reduced the number of relevant sites to 17 (Damholt & Surlyk, 2012).

In order to compare the 17 sites fulfilling the prerequisites with respect to their potential as a World Heritage Property, an additional number of issues were subsequently studied in detail under a second set of criteria (Sørensen, 2010):

The nature and quality of the rock section itself The site should be of high quality and permanency and contain a clearly defined stratigraphic section.	• Visibility of the boundary layer • Lateral extent of exposure • Quality of exposure
Fossil record of biodiversity The site should contain high fossil diversity, representing the broadest possible range of major taxonomic groups.	• Fossil diversity
Scientific impact of site The site should have high quality for scientific studies.	• Scientific impact • Accessibility of the site

The 17 short-listed Cretaceous-Palaeogene boundary sites were assessed as objectively as possible under the defined criteria, using numerical subcategories such as visibility of boundary layer, lateral extent, quality of exposure, presence of major biotic groups and number of scientific papers documenting the site for ranking within each criterion. The results were summed to produce a matrix for global comparative analysis.

Finally, the ranking found in the numerical comparative analysis was critically compared with the Statement of OUV of the nominated property as an outstanding example of the most spectacular global mass extinction event in the history of Earth (Damholt & Surlyk, 2012).

Integrity

While the principles of authenticity apply only to properties being nominated under criteria (i) – (vi), the concept of integrity applies to all nominations, including those under criterion (viii). Integrity is a measure of the wholeness or intactness of the heritage of the proposed property. Specifically, it must include all elements needed to express its OUV, it must be of adequate size to ensure the complete representation of the features and processes that convey the property's significance and it should not be suffering from any adverse effects of development and/or neglect. For all properties nominated under criteria (vii) – (x), bio-physical processes and landform features should be relatively intact. However, it is recognised that no area is totally pristine and that all natural areas are in a dynamic state, and to some extent involve contact with people. For criterion (viii) the Operational Guidelines (UNESCO World Heritage Centre, 2019) state that proposed properties:

> "…should contain all or most of the key inter-related and interdependent elements in their natural relationships. For example, an 'ice age' area would meet the conditions of integrity if it includes the snow field, the glacier itself and samples of cutting patterns, deposition and colonization (e.g. striations, moraines, pioneer stages of plant succession, etc.); in the case of volcanoes, the magmatic series should be complete and all or most of the varieties of effusive rocks and types of eruptions be represented."

Within this general context, other aspects of integrity are mostly specific to the theme and property under consideration. For example, a fossil property under Theme 1 should contain a high abundance and diversity of well-preserved fossils that remain *in situ* in the rock for observation and future study, and fossils that have been removed for scientific purposes should be reposited in a curated museum collection. The permanence of the fossil record at the property is also an important feature of its integrity.

Protection and management

Once a property is inscribed onto the World Heritage List, it is necessary that the State Party ensures the conditions and integrity of the property are sustained, or even enhanced. To achieve this all properties must have adequate long-term legislative, regulatory, institutional and /or traditional protection and management to ensure their safeguarding. The property should be protected from social, economic and other pressures that might negatively impact the property's OUV.

Boundaries

The delineation of boundaries is an essential requirement in the establishment of the effective protection of a property. For properties nominated under criteria (vii) – (x), boundaries should reflect the spatial requirements of habitats, species, processes or phenomena that provide the basis for their inscription on the World Heritage List. The boundaries should include sufficient areas immediately adjacent to the area of OUV in order to protect the property's heritage values from direct effects of human encroachments and impacts of resource use outside of the nominated area (a buffer zone). More information on protection and management and boundaries can be found in the Operational Guidelines (UNESCO World Heritage Centre, 2019).

Geological World Heritage Properties and UNESCO Global Geoparks

The following section addresses the explicit request from the World Heritage Committee for guidance on the relationship between geological World Heritage Properties and UNESCO Global Geoparks.

The 'Convention Concerning the Protection of the World Cultural and Natural Heritage' was adopted by the General Conference of UNESCO at its 17th session in November 1972. It was done in response to the observation that cultural and natural heritage were becoming increasingly threatened with destruction, not only by traditional causes of decay but also by changing social and economic conditions. It also considered that parts of the cultural and natural heritage are of outstanding interest and therefore need to be preserved as part of the World Heritage of humankind as a whole. At the time of adoption, the Convention stated that natural heritage included, "geological and physiographical formations." Subsequently the concept of OUV was defined and ten criteria were established to help States Parties decide whether proposed World Heritage Properties could fulfil the concept of OUV. Before 2004, natural criterion (i) stated, "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." With the re-organising of the criteria in 2004, natural criterion (i) became criterion (viii), although the definition remained unchanged. Presently (June 2021), 93 properties are inscribed on the World Heritage List either under criterion (viii) alone or in combination with one or more other criteria, representing approximately 8% of all properties on the list.

The latest version of the *Operational Guidelines for the Implementation of the World Heritage Convention* published in 2019 mentions that, since the adoption of the Convention in 1972, the international community has embraced the concept of 'sustainable development' and notes that the protection and conservation of the natural and cultural heritage constitute a significant contribution to sustainable development. It also encourages States Parties to mainstream into their programmes and activities related to the Convention the principles of the relevant policies adopted by the World Heritage Committee, the General Assembly of States Parties to the Convention and the UNESCO Governing Bodies. These include the document *Policy for the Integration of a Sustainable Development Perspective into the Processes of the World Heritage Convention* and the UNESCO policy on engaging with indigenous peoples, as well as other related policies and documents including the 2030 Agenda for Sustainable Development and international human rights standards. However, the definitions of World Heritage and OUV and the ten criteria that support these definitions still make no reference to sustainable development. Furthermore, some properties are so fragile, remote, scientifically specific or they simply have no host human communities that they cannot contribute to sustainable development. The important thing is, of course, that they fulfil one or more of the ten criteria to demonstrate that they have OUV.

Starting in the late 1980's and 1990's, various areas in Europe were developing programmes of sustainable development based on geological heritage. In 1994, Réserve Géologique de Haute Provence (France), Vulkaneifel (the Gerolstein area of the Eifel district in Germany) and the Museum of the Petrified Forest on Lesvos Island, Greece, joined together to apply for funding under the European Union's community-led LEADER programme to further develop this concept of using an area's geological heritage to promote the sustainable development of the communities who live there. They were joined by the Maestrazgo Cultural Park in Spain, and together in 2000, they jointly launched the fledging European Geoparks Network with each area branding itself as a European Geopark. As originally defined, a European Geopark is a territory, which includes a particular geological heritage and a sustainable territorial development strategy supported by a European program to promote development. It must have clearly defined boundaries and sufficient surface area for true territorial economic development. A European Geopark should have an active role in the economic development of its territory through enhancement of a general image linked to the geological heritage and the development of geotourism. It should also have direct impact on the territory by influencing its inhabitants living conditions and environment. The objective is to enable the inhabitants to re-appropriate the values of the territory's heritage and actively participate in the territory's cultural revitalisation as a whole. Also, significantly, all European Geoparks were obliged to be part of a network of cooperation, the European Geoparks Network. By early 2004, the European Geoparks Network had expanded to include 17 European Geoparks.

At the same time, Geoparks also began to be created in China. However, here the early focus was to define sites and areas important from a geological science perspective only, rather than using that heritage for promoting sustainable development. On February 13, 2004, alongside the annual meeting in UNESCO of the International Geoscience Programme (IGCP), eight Chinese Geoparks and the 17 European Geoparks were brought together to create the Global Geoparks Network (GGN) and the 25 European and Chinese Geoparks were rebranded as Global Geoparks, under the auspices of UNESCO, and using the approach of using geological heritage for promoting sustainable development. The Global Geoparks and the GGN were then formally launched in June 2004 in Beijing, China, at the inaugural International

Conference on Geoparks. The 2005 report noted that, "…the World Heritage List is never likely to include more than 150 properties of primary geological or geomorphological interest," and that the "necessarily selective nature of World Heritage cannot, therefore, be regarded as adequate for recognising the full range of globally selective geological properties." By the time the 2005 report was published, there were 32 Global Geoparks and it was noted that the UNESCO Geoparks Program could be a viable alternative model to World Heritage for recognising / protecting other geological sites. However, there was no UNESCO Geoparks Program at that time and there was no formal, legal link to UNESCO.

Nevertheless, Global Geoparks increasingly spread to other areas of the world. Starting in 2013, at the request of its Member States, UNESCO, through the establishment of a working group, began to explore ways of formalising the link between Global Geoparks and the Organisation. This resulted in the adoption in November 2015 by the General Conference of UNESCO at its 38th session of a new programme, the International Geoscience and Geoparks Programme (IGGP), which allowed for the creation of a new UNESCO site designation, the UNESCO Global Geopark (UGGp). Following approval from 33 individual Member States, which hosted the then existing 120 Global Geoparks, these areas were automatically re-designated as UGGp's. Presently (June 2021) there are 169 UGGp's in 44 Member States, all linked together through the GGN[4].

With the drafting and adoption of a set of Statutes and Operational Guidelines for the new IGGP (UNESCO, 2015), a UNESCO Global Geopark was officially defined as a:

> "…single, unified geographical areas where sites and landscapes of international geological significance are managed with a holistic concept of protection, education and sustainable development. The international geological significance of a UNESCO Global Geopark is determined by scientific professionals, as part of a 'UNESCO Global Geopark Evaluation Team', who make a globally comparative assessment based on the peer-reviewed, published research conducted on geological sites within the area. UNESCO Global Geoparks use geological heritage, in connection with all other aspects of that area's natural and cultural heritage, to enhance awareness and understanding of key issues facing society in the context of the dynamic planet we all live on."

To support this definition a set of seven criteria were also adopted:

(i) UNESCO Global Geoparks must be single, unified geographical areas where sites and landscapes of international geological significance are managed with a holistic concept of protection, education, research and sustainable development. A UNESCO Global Geopark must have a clearly defined border, be of adequate size to fulfil its functions and contain geological heritage of international significance as independently verified by scientific professionals.

(ii) UNESCO Global Geoparks should use that heritage, in connection with all other aspects of that area's natural and cultural heritage, to promote awareness of key issues facing society in the context of the dynamic planet we all live on, including but not limited to increasing knowledge and understanding of: geoprocesses; geohazards; climate change; the need for the sustainable use of Earth's natural resources; the evolution of life and the empowerment of indigenous peoples.

(iii) UNESCO Global Geoparks should be areas with a management body having legal existence recognized under national legislation. The management bodies should be appropriately equipped to adequately address the area of the UNESCO Global Geopark in its entirety.

(iv) In the case where an applying area overlaps with another UNESCO designated site, such as a World Heritage Site or Biosphere Reserve, the request must be clearly justified and evidence must be provided for how UNESCO Global Geopark status will add value by being both independently branded and in synergy with the other designations.

(v) UNESCO Global Geoparks should actively involve local communities and indigenous peoples as key stakeholders in the Geopark. In partnership with local communities, a co-management plan needs to be drafted and implemented that provides for the social and economic needs of local populations, protects the landscape in which they live and conserves their cultural identity. It is recommended that all relevant local and regional actors and authorities be represented in the management of a UNESCO Global Geopark. Local and indigenous knowledge, practice and management systems should be included, alongside science, in the planning and management of the area.

(vi) UNESCO Global Geoparks are encouraged to share their experience and advice and to undertake joint projects within the GGN. Membership of GGN is obligatory.

(vii) A UNESCO Global Geopark must respect local and national laws relating to the protection of geological heritage. The defining geological heritage sites within a UNESCO Global Geopark must be legally protected in advance of any application. At the same time, a UNESCO Global Geopark should be used as leverage for promoting the protection of geological heritage locally and nationally. The management body must not participate directly in the sale of geological objects such as fossils, minerals, polished rocks and ornamental rocks of the type normally found in so-called 'rockshops' within the UNESCO Global Geopark (regardless of their origin) and should actively discourage unsustainable trade in geological materials as a whole. Where clearly justified as a responsible activity and as part of delivering the most effective and sustainable means of site management, it may permit sustainable collecting of geological materials for scientific and educational purposes from naturally renewable sites within

4 List of UNESCO Global Geoparks - http://www.unesco.org/new/en/natural-sciences/environment/earth-sciences/unesco-global-geoparks/list-of-unesco-global-geoparks/

Figure 32: Lesvos Island UNESCO Global Geoparks (Greece). One of the remits of UNESCO Global Geoparks is to promote awareness of geohazards. On Lesvos Island the Geopark authorities teach school children how to act in the event of an earthquake. When this earthquake hit the village of Vrisa in 2017, pupils in the local school were in class. While the school was destroyed, all children escaped unharmed. © Patrick Mc Keever

the UNESCO Global Geopark. Trade of geological materials based on such a system may be tolerated in exceptional circumstances, provided it is clearly and publicly explained, justified and monitored as the best option for the Global Geopark in relation to local circumstances. Such circumstances will be subject to approval by the UNESCO Global Geoparks Council on a case by case basis.

As can be seen, the main and important differences between geological World Heritage Properties and UNESCO Global Geoparks include that the former are defined by the concept of OUV while the latter are defined by having 'sites and landscapes of international geological significance'. While OUV is defined as a combination of fulfilling one or more of the World Heritage criteria, site integrity and having a management plan, for UGGp's international geological significance is independently assessed by the International Union for Geological Sciences (IUGS). Through their global network, IUGS ask independent geological researchers on whether the areas' geological values have attracted international scientific researchers whose results have been published in international, peer-reviewed scientific journals. If the application is deemed by IUGS as not having international value, then the application is stopped.

Additionally, the concept of sustainable development is an integral part of the definition of a UGGp and the involvement of local communities is one of the criteria that helps support the definition. Furthermore, while UGGp's can, just like World Heritage Properties, be transnational they cannot be serial in nature as a UGGp is defined as a single, unified geographical area. Finally, a UGGp must include people within its boundaries as per criterion (v) of the definition and there is no zonation such as can exist for World Heritage Properties (e.g. buffer zones).

Legally, the two designations also differ. The Statutes and Operational Guidelines of the IGGP do not constitute an intergovernmental convention such as the 'World Heritage Convention' and decisions involving new designations and revalidation (the 4-yearly periodic review all UGGp's are subject to) are taken by a body of individuals, the UNESCO Global Geoparks Council, which is appointed by the Director General of UNESCO on the basis of their expertise in Geoparks but who are not representatives of their respective States or any other affiliated entity. This is in contrast to the equivalent body for World Heritage, the World Heritage Committee, which consists of representatives from 21 of the States Parties that are signatories to the Convention. The aforementioned system of periodic review for UGGp's, revalidation, also differs to that operated through the World Heritage Convention, the periodic review. During revalidation, progress reports submitted by the UGGp are analysed and this is followed by a site visit that thoroughly investigates not only whether the area is still functioning as a UGGp but, significantly, what improvements have been made, particularly in regard to sustainable

Figure 33: Cuilcagh Lakelands UNESCO Global Geopark (Northern Ireland & Republic of Ireland). Protection of internationally important geological environments is also part of the remit of UNESCO Global Geoparks. Cuilcagh Mountain holds one of the largest expanses of blanket bog in Europe. Erosion of the bog, for example by increased numbers of walkers, leads to increased rain runoff into the Marble Arch Caves. To assist in the protection of both the bog and the caves, the Geopark authorities built a walkway for ramblers. The wooden walkway has become a huge success and has attracted tens of thousands more walkers to the area but still ensuring protection of the environment while economically benefitting the sustainable tourism industry of the Geopark. © Tourism Ireland

development, community involvement and networking activities through the GGN. The result of this process can be that the area has made sufficient progress meaning it can maintain its designation as a UGGp for an additional four years, after which this process is repeated (the so-called green card). If, however, it is deemed that not enough progress has been made or one or more other issues have been identified (perhaps, for example, problems in management or visibility) then a two year warning is issued (the so-called yellow card). A list of recommendations are given to the UGGp and a two year period is allowed for their implantation after which another, full revalidation exercise is undertake. At this stage, if it is considered that not enough progress has been made then the area loses its designation as a UGGp (the so-called red card). A red card is not necessarily the end of the story however, as the area, when its management body feels it is ready, can re-apply following the normal procedure. Several Geoparks that previously were given red card have re-applied and have been re-designated as UGGp's.

While the two UNESCO designations have different remits and foci, the two are not mutually exclusive. There are several UGGp's that include within their boundaries one or more World Heritage Properties (cultural, natural and mixed), there are some UGGp's that have subsequently, either partially or wholly, been inscribed onto the World Heritage List. There are also some geological World Heritage Properties that have subsequently been incorporated into a UGGp (e.g. Messel Pit Fossil Site World Heritage Property in Germany is now a site within the much larger Bergstraße-Odenwald UGGp).

When a Member State of UNESCO or a State Party to the World Heritage Convention is pondering whether to apply for an area within its territory to be designated as a geological World Heritage Property or as a UGGp, the key questions they should ask is why do they want that designation and what is it they hope to achieve by obtaining it? The following figures (34 and 35) are aimed at helping countries decide.

	World Heritage Property	Unesco Global Geopark
Who Can Apply	Any country that has signed the World Heritage Convention. Such countries are known as States Parties.	Any country that is a member of UNESCO.
Geological Values	Must fulfil criterion (viii) and demonstrate OUV.	Must have sites and landscapes of international geological significance.
Who Decides On Geological Value	Recommendation made by IUCN. Decision made by World Heritage Committee.	International Union of Geological Sciences make decision. If they say 'no', the application is halted.
Role Of National Government	The nomination of a property for inscription on the World Heritage List is prepared by a State Party to the World Heritage Convention.	Notice of intent to apply and the application sent by the national organisation that has official relations with UNESCO e.g. national commission.
Tentative List	Obligatory	Recommended
National Committees	Not required	Recommended
Submission	Only a property already on the World Heritage Tentative List may be submitted by the State Party to the UNESCO World Heritage Centre as a new World Heritage nomination.	Through the national organisation that has official relations with UNESCO e.g. national commission.
Serial Properties/ Sites	Yes	No. Must be a single, unified area.
Other Values	Can be submitted under any other natural or cultural criteria so long as it can demonstrate OUV under each criterion.	Obligatory to link the geological values with other natural, cultural and intangible values.
Maximum Size	None	While there is no maximum size, it needs to be manageable by a single management authority.
Minimum Size	Must be of adequate size to ensure the complete representation of the features and processes which convey the property's significance and OUV.	Cannot be a single site and must be of sufficient size to realise sustainable economic development.
Management Body	Obligatory.	Obligatory.
Overlap With Other Unesco Designations	Yes.	Yes but the reasons must be detailed in the application and the management body of any other designation must support the UGGp application.
Local Community Involvement	Recommended where appropriate.	Obligatory.
Areas With No Human Population	Yes.	No.
Selling Of Geological Material In So-Called 'Rock Shops'	Yes.	Not permitted by any organisation selling such material that is linked to the management body.
Networking With Other Sites In The Same Designation	No.	Obligatory. All UGGp's must be members of the Global Geoparks Network.
Cost Of Application Process	World Heritage Properties need an established protection and management regime that meets the World Heritage standard, but the cost of running such very much depends on site-specific characteristics. Costs associated with the nomination varies.	Area must demonstrate it is acting as a de-facto UGGp at the time of application including employing staff, operational activities, visibility etc. Costs associated with this varies. Costs associated with creation of application dossier also vary but normally less that WHS applications.

Figure 34: A compilation of common questions comparing geological World Heritage Properties and UNESCO Global Geoparks.

	World Heritage Property	Unesco Global Geopark
Cost Of Site Assessment	Costs borne by the nominating State Party.	Costs borne by the applying area.
Annual Fee	None.	A fee of 1,500€ is payable annually to the GGN of which 1,000USD is donated to UNESCO.
Application Timeline	Sites need to have been inscribed on the Tentative List for at least 12 months before being nominated. Nomination process from voluntary draft deadline takes a minimumn of 22 months.	Minimum of approximately 18 months. At the time of application, the candidate area must be acting as a de-facto Geopark for at least one year.
Decision Making Process	By the intergovernmental World Heritage Committee.	By the international UNESCO Global Geopark Council. Final endorsement is by the Executive Board of UNESCO.
Review Process	Every six years, States Parties submit periodic reports for examination by the World Heritage Committee. The state of conservation of specific World Heritage Properties that are under threat is reported by the State Party and analysed by the Advisory Bodies.	Four year revalidation process using a traffic light system of green (four year renewal), yellow (two year renewal) and red (delisting).
Expectation For Results Regarding Sustainable Development	States Parties to the World Heritage Convention, have the responsibility to contribute to and comply with the sustainable development objectives, including gender equality, in the World Heritage processes and in their heritage conservation and management systems.	Obligatory and assessed during the revalidation process.

Figure 34: A compilation of common questions comparing geological World Heritage Properties and UNESCO Global Geoparks.

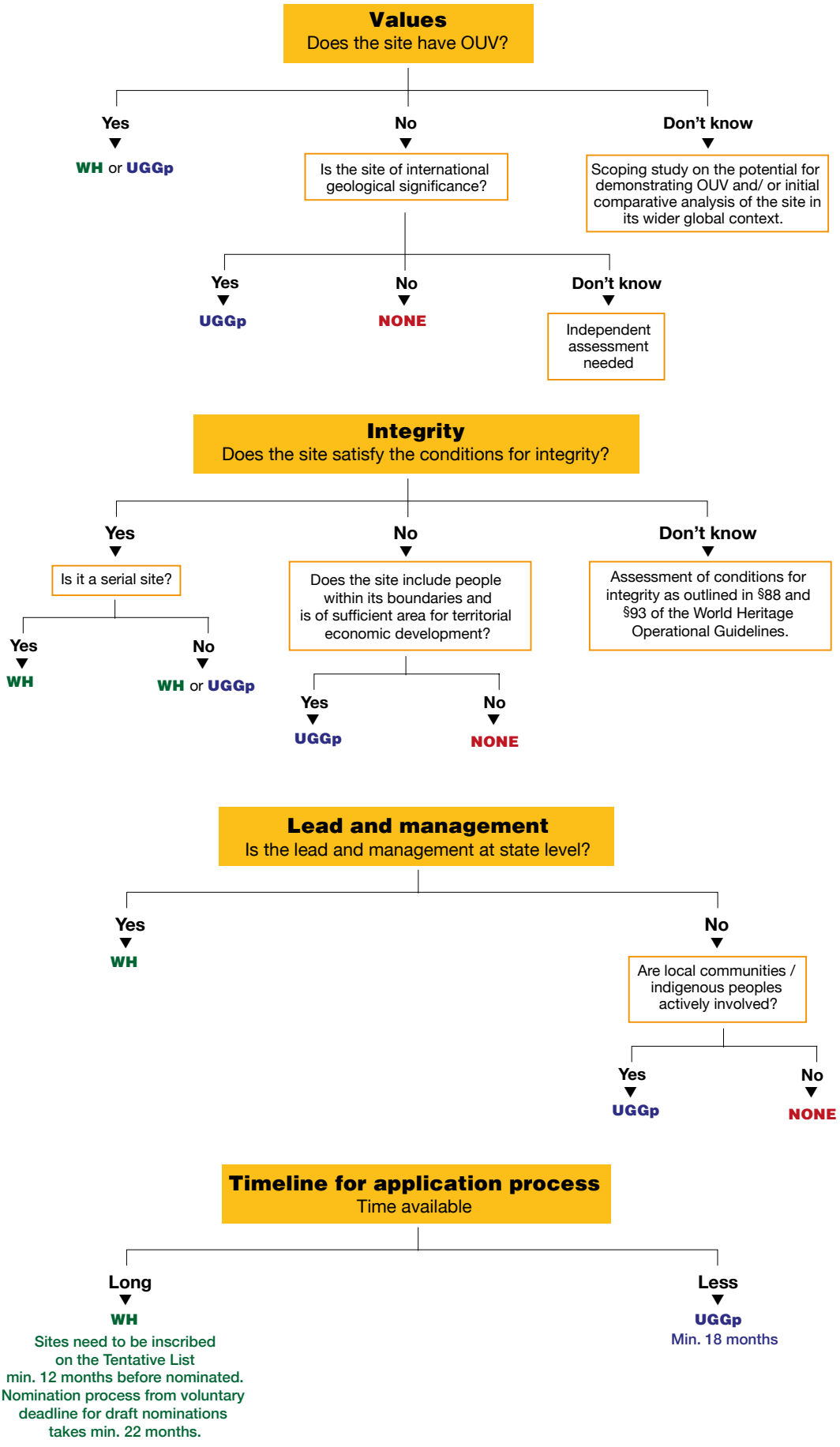


Figure 35: A Decision Tree aimed at further assisting countries decide whether to seek designation for an area as a geological World Heritage Property or a UNESCO Global Geoparks.

Conclusions

Figure 36: Grand Canyon National Park (United States of America). Carved out by the Colorado River, the Grand Canyon (nearly 1,500 m deep) is the most spectacular gorge in the world. Located in the state of Arizona, it cuts across the Grand Canyon National Park and its horizontal strata retrace the geological history of the past two billion years. © U.S. National Park Service

As was stated at the outset of this report, the 2005 report entitled *Geological World Heritage: A Global Framework*, aimed to discuss and advise on the role of the World Heritage Convention in recognising and protecting geological and geomorphological heritage. By using a thematic approach, the 2005 report aimed to:

- assist States Parties in undertaking global comparative analyses of properties prior to and as part of new nominations under criterion (viii);
- assist the World Heritage Committee and its advisors to identify possible gaps in coverage of the World Heritage List;
- assist the World Heritage Committee and its advisors in their evaluation of new nominations of properties under criterion (viii).

The remit of the present report is to fully revise and update the 2005 report and to look at the potential impact of the new UNESCO Global Geopark designation on future inscriptions to the World Heritage List under criterion (viii).

As with the 2005 report, this report also emphasises the fundamental nature of demonstrating OUV before any nomination to the World Heritage List should be made. It must be further emphasised that the World Heritage List is very selective and just because a site may be the best of its type nationally, or even on a continental scale, it does not automatically follow that it has the necessary OUV to be inscribed onto the World Heritage List. Only the best sites on a global scale should be inscribed.

Before starting the process of considering a possible nomination (and preferably before addition of a possible site to the national Tentative List that guides possible World Heritage nominations), consideration should be given to the reason for seeking a nomination. What is it the State Party wants to achieve by a nomination? At this stage, consideration should be given to assessing whether the UNESCO Global Geopark designation may be a more appropriate option to consider. The decision tree in the previous section (Figure 35) can help with this assessment.

Whether the decision is to press ahead with a World Heritage nomination or an application to become a UNESCO

Global Geopark, all the geological values of the site under consideration must be analysed. For a World Heritage nomination, the site must demonstrate OUV. For a UNESCO Global Geopark application, the proposed site or landscape must demonstrate geological heritage of international value.

To assist with the analysis in relation to possible World Heritage nominations, the 11 themes described in this report should be used to organise the information needed to consider the geological values of the proposed site. Overlaps between the geological values of the proposed site and gaps in the World Heritage List should be identified to ensure that these values are not already well represented. If the values overlap with identified gaps in the List, a brief synthesis defining these values and the attributes should be compiled as the basis for further analysis.

Finally, to ensure the proposed site really can demonstrate OUV, a thorough and detailed comparative analysis should be undertaken based on its geological values, attributes and integrity, to demonstrate that the site has the exceptional level of global significance that could justify its inclusion on the World Heritage List, and fully meet the requirements set out in the World Heritage Convention's *Operational Guidelines*.

Only once this has been done and the State Party can fully demonstrate that the site has the necessary potential to demonstrate OUV, should the preparation of a full nomination to the World Heritage List be considered. Throughout this process, IUCN is available to respond to questions and advice of States Parties considering World Heritage nominations, and welcomes further questions on the recommendations put forward in the present study.

References

Abdulla, A., Obura, D., Bertzky, B. and Shi, Y. (2013). *Marine Natural Heritage and the World Heritage List: Interpretation of World Heritage criteria in marine systems, analysis of biogeographic representation of sites, and a roadmap for addressing gaps*. Gland, Switzerland: IUCN. https://www.iucn.org/node/21147

Alvarez, L.W., Alvarez, W., Asaro, F. and Michel, H.V. (1980). Extraterrestrial cause for the Cretaceous–Tertiary Extinction. *Science*, 208(4448), pp.1095–1108. https://doi.org/10.1126/science.208.4448.1095

Anderson, J.M. and de Wit, M. (2008). Africa Alive Corridors. A continental network of earth, life and cultural heritage. *Geobulletin of the Geological Society of South Africa,* December 2008, pp. 11–25.

Baldursson, S., Guðnason, J., Hannesdóttir, H. and Thórðarson, T. (2018). *Nomination of Vatnajökull National Park for inclusion in the World Heritage List*. Reykjavík: Vatnajökull National Park. https://whc.unesco.org/document/166300

Bird, E.C. (2004). 'Coastal Classification'. In: A.S. Goudie (ed.) *Encyclopaedia of Geomorphology*, Routledge, London, vol 1, p. 165-168.

Bosson, J.-B., Huss, M., and Osipova, E. (2019). Disappearing World Heritage glaciers as a keystone of nature conservation in a changing climate. *Earth's Future*, 7, 469–479. https://doi. org/10.1029/2018EF001139

Casadevall, T., Tormey, D. and Roberts, J. (2019). *World Heritage Volcanoes: Classification, gap analysis, and recommendations for future listings*. Gland, Switzerland: IUCN. https://doi.org/10.2305/IUCN.CH.2019.07.en

Damholt, T. and Surlyk, F. (2012). *Nomination of Stevns Klint for inclusion in the World Heritage List*. St. Heddinge, Denmark: Østsjællands Museum.

Dingwall, P., Weighell, T. and Badman, T. (2005). *Geological World Heritage: A Global Framework*. Gland, Switzerland: IUCN. https://www.iucn.org/content/geological-world-heritage-a-global-framework

Dye, B.J. et al. (2019). *Heritage Dammed: Water Infrastructure Impacts on World Heritage Properties and Free Flowing Rivers*. Civil Society Report to the UNESCO World Heritage Committee and Parties of the World Heritage Convention. Moscow: Rivers without Boundaries and World Heritage Watch. https://portals.iucn.org/library/node/48506

Fan, J.-X. et al. (2020). A high-resolution summary of Cambrian to Early Triassic marine invertebrate biodiversity. *Science* 367(6475), pp.272–277. https://doi.org/10.1126/science.aax4953

Ferrier, R.C. and Jenkins, A. (eds.) (2010). *Handbook of catchment management*. Chichester: Wiley-Blackwell. https://doi.org/10.1002/9781444307672

Ford, D.C. and Williams, P.W. (2007). *Karst Hydrogeology and Geomorphology*. Chichester: Wiley.

Ford, D.C. and Williams, P.W. (2011). 'Geomorphology underground: the study of karst and karst processes'. In: K.J. Gregory and A.S. Goudie (eds.) *The SAGE Handbook of Geomorphology*. London: SAGE Publications.

Freestone, D., Laffoley, D., Douvere, F. and Badman, T. (2016). *World Heritage in the High Seas: An Idea Whose Time Has Come*. World Heritage Report 44. UNESCO and IUCN.

Fryirs, K.A. and Brierley, G.J. (2012). *Geomorphic analysis of river systems: an approach to reading the landscape*. John Wiley & Sons.

Goldscheider, N. et al. (2020). Global distribution of carbonate rocks and karst water resources. *Hydrogeology Journal* 28, 1661-1677. https://doi.org/10.1007/s10040-020-02139-5

Goudie, A. and Seely, M. (2011). *World Heritage Desert Landscapes: Potential Priorities for the Recognition of Desert Landscapes and Geomorphological Sites on the World Heritage List.* Gland, Switzerland: IUCN. https://portals.iucn.org/library/node/9818

Grill, G. et al. (2019). Mapping the world's free-flowing rivers. *Nature*, *569*(7755), p.215. https://doi.org/10.1038/s41586-019-1111-9

Henriques, M.H. and Neto, K. (2015). Geoheritage at the Equator: Selected Geoproperties of Sao Tome Island (Cameron Line, Central Africa). *Sustainability*, v. 7, pp. 648-667. https://doi.org/10.3390/su7010648

Hillier, J.K. and Watts, A.B. (2007). Global distribution of seamounts from ship-track bathymetry data. *Geophys. Res. Lett.* 34: L13304. https://doi.org/10.1029/2007GL029874.

International Union for Conservation of Nature (IUCN) (2016). 'World Heritage Nomination – IUCN Technical Evaluation, Mistaken Point (Canada)'. In: *IUCN World Heritage Evaluations 2016*. IUCN Evaluations of nominations of natural and mixed properties to the WHL. WHC/16/40.COM/INF.8B2. Gland, Switzerland: IUCN, pp.53-62. https://whc.unesco.org/document/152802

IUCN (2019). 'World Heritage Nomination – IUCN Technical Evaluation, Vatnajökull National Park (Iceland)'. In: *IUCN World Heritage Evaluations 2019*. IUCN Evaluations of nominations of natural and mixed properties to the World Heritage List. WHC/19/43.COM/INF.8B2. Gland, Switzerland: IUCN, pp.42-51. https://whc.unesco.org/document/176191

Kim, S. and Wessel, P. (2011). New global seamount census from altimetry-derived gravity data. *Geophysical Journal International* 186: 615-631. https://doi.org/10.1111/j.1365-246X.2011.05076.x

Moss, B. (2010). *Ecology of fresh waters: a view for the twenty-first century*. John Wiley & Sons.

Osinski, G.R. and Pierazzo, E. (2012). *Impact Cratering: Processes and Products*. John Wiley & Sons.

Palmer, A.N. (2007). *Cave Geology*. Dayton, Ohio: Cave Books.

Raup, D.M. and Sepkoski, J.J. (1982). Mass extinctions in the marine fossil record. *Science* 215(4539), pp.1501-1503. https://doi.org/10.1126/science.215.4539.1501

Sørensen, A.M. (2010). *Comparative analysis of K/T boundary sites for inclusion in the World Heritage List*. Report. Østsjællands Museum.

Spalding, M.D. (2012). *Marine World Heritage: Towards a representative, balanced, and credible World Heritage List*. UNESCO World Heritage Centre, Paris. Online: whc.unesco.org/uploads/activities/documents/activity-13-24.pdf

Thomas, R. and Narbonne, G.M. (2015). *Mistaken Point: Nomination for inscription on the UNESCO World Heritage List*. Newfoundland and Labrador, Canada: Parks and Natural Areas Division of the Department of Environment and Conservation, and Mistaken Point Ambassadors Inc. https://whc.unesco.org/uploads/nominations/1497.pdf

Thorsell, J.W., Levy, R.F and Sigaty, T. (1997). *A global overview of wetland and marine protected areas on the World Heritage list*. Gland, Switzerland: IUCN. https://portals.iucn.org/library/node/7359

Toteu, S.F., Anderson, J.M. and De Wit, M. (2010). 'Africa Alive Corridors': Forging a new future for the people of Africa. *Journal of African Earth Sciences* 58, pp.692–715. https://doi.org/10.1016/j.jafrearsci.2010.08.011

United Nations Educational, Scientific and Cultural Organization (UNESCO) (2015). *The Statutes and Operational Guidelines of the International Geoscience and Geoparks Programme*. IGGP/2015/ST.

UNESCO (2016). The future of the World Heritage convention for marine conservation. *UNESCO World Heritage paper* 45.

UNESCO World Heritage Centre (2011). *Preparing World Heritage Nominations.* 2nd ed*. A World Heritage Resource Manual*. Paris, France.

UNESCO World Heritage Centre (2019). *Operational Guidelines for the Implementation of the World Heritage Convention*. WHC.19/01 10 July 2019. Paris, France.

Wessel, P., Sandwell, D.T. and Kim, S. (2010). The Global Seamount Census. *Oceanography* 23: 24-33.

Wells, R.T. (1996). *Earth's Geological History: A Contextual Framework for Assessment of World Heritage Fossil Site Nominations.* IUCN Natural Heritage Programme Working Paper 1. Gland, Switzerland: IUCN. https://portals.iucn.org/library/node/7357

Williams, P. (2008). *World Heritage Caves and Karst: A Thematic Study*. Gland, Switzerland: IUCN. https://www.iucn.org/content/world-heritage-caves-and-karst-a-thematic-study

Wood, C. (2009). *World Heritage Volcanoes*. Gland, Switzerland: IUCN. https://portals.iucn.org/library/node/9486

Woodroffe, C.D., Cowell, P.J. and Dickson, M.E. (2011). 'Coastal Environments'. In K.J. Gregory and A.S. Goudie (eds.) *The SAGE Handbook of Geomorphology*. London: SAGE Publications.

World Heritage Committee (2014). Decision 38 COM 8B.10. Stevns Klint (Denmark). In: *Report of decisions of the 38th session of the World Heritage Committee* (Doha, 2014). Paris, France: UNESCO World Heritage Centre, https://whc.unesco.org/en/decisions/6095/

World Wide Fund for Nature (WWF) (2019). New study in Nature: Just one-third of the world's longest rivers remain free-flowing. 8 May 2019. Gland, Switzerland: WWF. https://wwf.panda.org/wwf_news/press_releases/?346815/New-Study-in-Nature-Just-One-Third-of-the-Worlds-Longest-Rivers-Remain-Free-Flowing

Annex 1: Table of geological World Heritage Properties

Guy M. Narbonne and José Brilha

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Australian Fossil Mammal Sites (Riversleigh / Naracoorte)	1		Riversleigh provides exceptional, and in many cases unique, mammal assemblages from the Oligocene to Miocene, spanning from 10-30 million years ago. These assemblages document changes in habitat from humid, lowland rainforest to dry eucalypt forests and woodlands, and provide the first fossil record for many distinctive groups of living mammals such as the marsupial moles and feather-tailed possums. The assemblages recovered from the caves at Naracoorte Victoria Fossil Cave preserve an outstanding record of more recent terrestrial vertebrate life. These open a window into a significant period of Earth's history from the mid-Pleistocene to present (530,000 years ago to today), a period characterised by great climatic changes.	**Theme 1:** Riversleigh and Naracoorte are a superb illustration of key stages in the Cenozoic evolution of Australia's unique fauna.	1994	(viii)(ix)	Natural	Australia	Asia and the Pacific
Barberton Makhonjwa Mountains	1	2, 4, 11	Decision: 42 COM 8B.5 states: The property contains the best, most diverse and outstanding examples of rock outcrops from the Archaean stage of Earth's history. Its rocks have revealed the earliest record of single-celled life forms as well as the earliest and most significant geomorphic features, including detailed evidence of the processes involved in the evolution of the originally oxygen-free oceans and atmosphere, and creation of the first continental landforms. The property is a truly unique remnant of the ancient Earth's crust, containing among the oldest, and undoubtedly the best-preserved sequence of volcanic and sedimentary rocks on Earth. These highly accessible ancient exposures present a continuous 340 million year sequence of rocks, starting 3600 million years ago. Their physical and chemical characteristics provide an unparalleled source of scientific information about the early Earth. The outstanding value of these rocks lies in the large number of sites and features that, when combined, provide a unique, and as yet only partially explored, scientific resource.	**Theme 1:** One of the world's oldest geological structures, dating back 3.6 to 3.25 billion years ago, preserving the environment for the early evolution of life. **Theme 2:** An Archean granite-greenstone belt that records continent-building on the early Earth. **Theme 4:** Komatiites, the hottest lavas that have ever flowed on our planet, were first recognized in this site. **Theme 11:** Spherule beds of molten rock droplets from a period of intense meteorite bombardment, which provide evidence of some of the earliest large meteorite impact events.	2018	(viii)	Natural	South Africa	Africa

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Canadian Rocky Mountain Parks	1	2, 6	The Burgess Shale is one of the most significant fossil areas in the world. Exquisitely preserved fossils record a diverse, abundant marine community dominated by soft-bodied organisms. Originating soon after the rapid unfolding of animal life about 540 million years ago, the Burgess Shale fossils provide key evidence of the history and early evolution of most animal groups known today, and yield a more complete view of life in the sea than any other site for that time period. The seven parks of the Canadian Rockies are a classic representation of significant and on-going glacial processes along the continental divide on highly faulted, folded and uplifted sedimentary rocks.	**Theme 1:** The Burgess Shale, inscribed as a UNESCO World Heritage Property in 1980 for its world-renown fossils of Cambrian soft-bodied marine animals, is now included in this property. **Theme 2:** The contiguous national parks of Banff, Jasper, Kootenay and Yoho, as well as the Mount Robson, Mount Assiniboine and Hamber provincial park forms a striking mountain landscape. **Theme 6:** Includes large areas of limestones and dolomites. Outstanding example of glaciokarst terrain. Many karren, subterranean streams, springs and caves. Columbia Icefield partly overlies and intrudes Castleguard Cave.	1984 (1990)	(vii)(viii)	Natural	Canada	Europe and North America
Canaima National Park	3	2, 5, 6	No approved retrospective Statement of OUV, but the inscription references the following Earth science values: Three different erosion surfaces are to be found within the park. The oldest rocks are Precambrian and, around 1,700 million years old, are some of the oldest on the planet. Above these are younger formations which have been weathered into mountains by 500 million years of erosion. The geology provides evidence that South America and Africa once formed part of a single continent. The property displays a distinctive and outstanding tepui landscape, which is still evolving in response to natural processes at large scale. The landscape also demonstrates the interaction of the indigenous Pemón with the environment both because of the great use the Pemón make of the park's natural resources and because of the way the park's landscape and vegetation has been shaped by the Pemón.	**Theme 3:** Tabular hills and high escarpments with significant karstic erosion of quartzites. Theme 2: Roughly 65% of the park is covered by table mountain (tepui) formations. **Theme 5:** Angel Falls in Canaima Natinal Park is the highest waterfalls in the world. **Theme 6:** The most outstanding example in the world of cave development in quartzite (Precambrian age). Caves occur to 10.8 km long and 383 m deep. Enclosed depressions and stream-sinks on plateau (tepuy) surface around 2,650 m. Springs emerge in tepuy walls. A fluviokarst landscape.	1994	(vii)(viii) (ix)(x)	Natural	Venezu-ela	Latin America and the Caribbean

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Carlsbad Caverns National Park	6		Carlsbad Caverns National Park is one of the few places in the world where on-going geologic processes are most apparent and rare speleothems continue to form, enabling scientists to study geological processes in a virtually undisturbed environment. These speleothems include helictites forming underwater, calcite and gypsum speleothems, and an astonishing collection of 'biothems', cave formations assisted in their formation by bacteria. Researchers can study both the Capitan reef's inside through cave passages that penetrate in and through it as well as eroded canyon-exposed cross sections outside.	**Theme 6:** Huge caverns extensively decorated with speleothems are a major feature of the park. The 81 known caves mainly occur in uplifted Permian reef limestones. Outstanding karst extends into neighbouring Guadalupe National Park. The region's caves provide the world's foremost example of evolution by sulphuric acid dissolution, which occurred progressively between 12 and 4 million years ago. Surface topography on backreef dolomites and limestones is dominated by dry valleys. High biodiversity, including about 1 million bat population.	1995	(vii)(viii)	Natural	United States of America	Europe and North America
Caves of Aggtelek Karst and Slovak Karst	6		The property Caves of Aggtelek Karst and Slovak Karst, while typical of many karst localities in Europe, is distinctive in its great number (with 712 recorded at time of inscription) of different types of caves found in a concentrated area. Geological processes causing karst features to be buried by sediment and then later reactivated or exhumed provide evidence pertaining to the geologic history of the last tens of millions of years. Relicts of pre-Pleistocene karst (i.e. more than about 2 million years old) are very distinct in the area, and many of them show evidence for sub-tropical and tropical climate forms. These include rounded hills that are relicts of tropical karst later modified by Pleistocene periglacial weathering. This suite of paleokarst features, showing a combination of both tropical and glacial climates, is very unusual and is probably better documented in the Slovak Karst than anywhere else in the world.	**Theme 6:** Area contains 712 caves. Variety of cave types, including Dobšinská Ice Cave, and speleothem forms with stalagmites to 32.7 m high. Surface landscape is a temperate doline karst with some evidence of a prior humid tropical or subtropical influence, which has evolved intermittently since the Cretaceous	1995 (2000)	(viii)	Natural	Hungary, Slovakia	Europe and North America

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Chaîne des Puys - Limagne fault tectonic arena	2		Continental drift, manifested through plate tectonics, is an essential paradigm for the history of the Earth as it explains the current make-up of oceans and continents and their past and future movements. The property is an exceptional illustration of the phenomenon of continental break-up, or rifting, which is one of the five major stages of plate tectonics. The Chaîne des Puys - Limagne fault tectonic arena presents a coincident view of all the representative processes of continental break-up and reveals their intrinsic links. The geological formations of the property, and their specific layout, illustrate with clarity this planet-wide process and its effects on a large and small scale on the landscape. This concentration has a demonstrated global significance in terms of its completeness, density and expression and has contributed to the site's prominence since the 18th century for the study of classical geological processes.	**Theme 2:** Situated in the centre of France, the property comprises the long Limagne fault, the alignments of the Chaîne des Puys volcanoes and the inverted relief of the Montagne de la Serre. It is an emblematic segment of the West European Rift, created in the aftermath of the formation of the Alps, 35 million years ago. The geological features of the property demonstrate how the continental crust cracks, then collapses, allowing deep magma to rise and cause uplifting at the surface. The property is an exceptional illustration of continental break-up – or rifting – which is one of the five major stages of plate tectonics.	2018	(viii)	Natural	France	Europe and North America

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Chengjiang Fossil Site	1		The Chengjiang Fossil Site presents an exceptional record of the rapid diversification of life on Earth during the early Cambrian Period, 530 million years before present. In this geologically short interval almost all major groups of animals had their origins. The property is a globally outstanding example of a major stage in the history of life, representing a palaeobiological window of great significance. The exceptional palaeontological evidence of the Chengjiang Fossil Site is unrivalled for its rich species diversity. To date at least 16 phyla, plus a variety of enigmatic groups, and about 196 species have been documented. Taxa recovered range from algae, through sponges and cnidarians to numerous bilaterian phyla, including the earliest known chordates. The earliest known specimens of several phyla such as cnidarians, ctenophores, priapulids, and vertebrates occur here. Many of the taxa represent the stem groups to extant phyla and throw light on characteristics that distinguish major taxonomic groups. The property displays excellent quality of fossil preservation including the soft and hard tissues of animals with hard skeletons, along with a wide array of organisms that were entirely soft-bodied, and therefore relatively unrepresented in the fossil record. Almost all of the soft-bodied species are unknown elsewhere. Fine-scale detailed preservation includes features as the alimentary systems of animals, for example of the arthropod Naraoia, and the delicate gills of the enigmatic Yunnanozoon. The sediments of Chengjiang provide what are currently the oldest known fossil chordates, the phylum to which all vertebrates belong. The fossils and rocks of the Chengjiang Fossil Site, together, present a complete record of an early Cambrian marine community. It is one of the earliest records of a complex marine ecosystem, with food webs capped by sophisticated predators. Moreover, it demonstrates that complex community structures had developed very early in the Cambrian diversification of animal life, and provides evidence of a wide range of ecological niches. The property thus provides a unique window of understanding into the structure of early Cambrian communities	**Theme 1:** Chengjiang's fossils present the most complete record of an early Cambrian marine community with exceptionally preserved soft-bodied and shelly fossils, comprising more than 200 species representing at least sixteen phyla of early animals.	2012	(viii)	Natural	China	Asia and the Pacific

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
China Danxia	3		China Danxia contains a wide variety of well-developed red-beds landforms such as peaks, towers, mesas, cuestas, cliffs, valleys, caves and arches. Being shaped by both endogenous forces (including uplift) and exogenous forces (including weathering and erosion), China Danxia provides a range of different aspects of the phenomenon of physical landscape developed from continental (terrestrial) reddish conglomerate and sandstone in a warm, humid monsoon climate, illustrating both the range of landforms in relation to the forces and processes that formed them. The component parts represent the best examples of 'least eroded' to 'most eroded' Danxia landforms, displaying a clear landform sequence from 'young' through 'mature' to 'old age', and with each component part displaying characteristic geomorphologic features of a given stage.	**Theme 3:** Diverse erosional topographies on continental red beds, predominantly sandstone and conglomerate	2010	(vii)(viii)	Natural	China	Asia and the Pacific
Desembarco del Granma National Park	6	7	The uplifted marine terraces of Desembarco del Granma National Park (DGNP), and the continuing development of karst topography and features, are a globally significant illustration of geomorphologic and physiographic features and ongoing geological processes. DGNP displays a rare relief formed by the combination of tectonic movements in the still active contact zone between two tectonic plates and the effects of past sea level change in response to climate fluctuations. The karst forms include escarpments, cliffs, cave systems, river canyons and large sinkholes known as dolines in most diverse sizes and shapes.	**Theme 6, 7:** Spectacular staircase of uplifted coral terraces around Cabo Cruz that support ongoing development of karst landforms. Terraces extend from -180 m offshore to 460 m inland and reflect a combination of tectonic and glacio-eustatic processes. Excellent examples of littoral karst. Relatively recent uplift has permitted the commencement of karstification.	1999	(vii)(viii)	Natural	Cuba	Latin America and the Caribbean

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Dinosaur Provincial Park	1		The property is outstanding in the number and variety of high quality specimens representing every known group of Cretaceous dinosaurs. The diversity affords excellent opportunities for paleontology that is both comparative and chronological. Over 350 articulated specimens from the Oldman and Dinosaur Park formations including more than 150 complete skeletons now reside in more than 30 major museums. In addition to the significant number of high quality specimens, the property contains a complete assemblage of non-dinosaurian fossil material offering an unparalleled opportunity for the study of the Late Cretaceous paleo-ecosystem.	**Theme 1:** Dinosaur Provincial Park contains some of the most important fossil discoveries ever made from the Cretaceous, in particular about 35 species of dinosaurs dating back some 75 million years.	1979	(vii)(viii)	Natural	Canada	Europe and North America
Dorset and East Devon Coast	1	7	The coastal exposures along the Dorset and East Devon coast provide an almost continuous sequence of Triassic, Jurassic and Cretaceous rock formations spanning the Mesozoic Era and document approximately 185 million years of Earth's history. The property includes a range of globally significant fossil localities - both vertebrate and invertebrate, marine and terrestrial - which have produced well preserved and diverse evidence of life during Mesozoic times. It also contains textbook exemplars of coastal geomorphological features, landforms and processes. Renowned for its contribution to Earth science investigations for over 300 years, the Dorset and East Devon coast has helped foster major contributions to many aspects of geology, palaeontology and geomorphology and has continuing significance as a high quality teaching, training and research resource for the Earth sciences.	**Theme 1:** Superb coastal exposures provide an almost continuous sequence of Triassic, Jurassic and Cretaceous rock formations spanning the Mesozoic Era and document approximately 185 million years of Earth history. **Theme 7:** It also contains textbook exemplars of coastal geomorphological features, landforms and processes.	2001	(viii)	Natural	United Kingdom of Great Britain and Northern Ireland	Europe and North America

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Durmitor National Park	3		Durmitor National Park harbours a wealth of geological and geomorphological features of major scientific interest which have been shaping the landscape, such as the many remarkable Karst phenomena. The dominant geological features are very thick, often savagely contorted limestone formations of the Middle and Upper Triassic, Upper Jurassic and Upper Cretaceous though more recent rocks are also present. One particularity is the so-called Durmitor Flysch, a term used for tectonic layers inclined at an angle of 90 degrees in the Durmitor Massif. The sheer walls of the many canyons, and in particular, those of the spectacular Tara River Gorge of more than 60 km, are not only fundamental landscape features of the park but also expose magnificent rock formations. Less known but no less fascinating is the underground world of the property. It includes Montenegro's deepest cave and subterranean rivers draining some of the glacial lakes. In particular, the 'Ice Cave' is a visually stunning and a rare relict of past glaciation.	**Theme 3:** This breathtaking national park was formed by glaciers and is traversed by rivers and underground streams. The Tara River canyon which has the deepest gorges in Europe.	1980 (2005)	(vii)(viii)(x)	Natural	Montene-gro	Europe and North America
El Pinacate and Gran Desierto de Altar Biosphere Reserve	10	4	The property's desert and volcanic landforms provide an exceptional combination of features of great scientific interest. The vast sea of sand dunes that surrounds the volcanic shield is considered the largest and most active dune system in North America. It includes a diverse range of dunes that are nearly undisturbed, and include spectacular and very large star-shaped dunes that occur both singly and in long ridges up to 48km in length. The volcanic exposures provide important complementary geological values, and the desert environment assures a dramatic display of a series of impressive large craters and more than 400 cinder cones, lava flows, and lava tubes. Taken together the combination of Earth science features is an impressive laboratory for geological and geomorphological studies.	**Theme 10:** The property includes part of the Sonoran Desert, with star dunes and linear dunes of considerable height. **Theme 4:** The 714,566 ha property comprises two distinct parts: the dormant volcanic Pinacate Shield of black and red lava flows and more than 400 monogenetic cinder cones and maars of Holocene age.	2013	(vii)(viii)(x)	Natural	Mexico	Latin America and the Caribbean
Everglades National Park	5, 7		The Everglades is a vast, nearly flat, seabed that was submerged at the end of the last Ice Age. Its limestone substrate is one of the most active areas of modern carbonate sedimentation.	**Theme 5, 7:** A river of grass flowing imperceptibly from the hinterland into the sea	1979	(viii)(ix)(x)	Natural	United States of America	Europe and North America

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Fraser Island	7		The property represents an outstanding example of significant ongoing geological processes including longshore drift. The immense sand dunes are part of the longest and most complete age sequence of coastal dune systems in the world and are still evolving. The superimposition of active parabolic dunes on remnants of older dunes deposited during periods of low sea level, which are stabilised by towering rainforests at elevations of up to 240 m, is considered unique. Fraser Island also has a variety of freshwater dune lakes which are exceptional in terms of number, diversity and age. The dynamic interrelationship between the coastal dune sand mass, aquifer hydrology and the freshwater dune lakes provides a sequence of lake formation both spatially and temporally. The process of soil formation on the island is also unique, since as a result of the successive overlaying of dune systems, a chronosequence of podzol development from the younger dune systems on the east to the oldest systems on the west change from rudimentary profiles less than 0.5 m thick to giant forms more than 25 m thick. The latter far exceeds known depths of podzols anywhere else in the world and has a direct influence on plant succession, with the older dune systems causing retrogressive succession when the soil horizon becomes too deep to provide nutrition for tall forest species.	**Theme 7:** Fraser Island is the largest sand island in the world. The combination of shifting sand-dunes, tropical rainforests and lakes makes it an exceptional site.	1992	(vii)(viii) (ix)	Natural	Australia	Asia and the Pacific

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Galápagos Islands	2, 4	7, 8	The archipelago´s geology begins at the sea floor and emerges above sea level where biological processes continue. Three major tectonic plates—Nazca, Cocos and Pacific— meet at the basis of the ocean, which is of significant geological interest. In comparison with most oceanic archipelagos, the Galápagos are very young with the largest and youngest islands, Isabela and Fernandina, with less than one million years of existence, and the oldest islands, Española and San Cristóbal, somewhere between three to five million years. The property demonstrates the evolution of the younger volcanic areas in the west and the older islands in the east. On-going geological and geomorphological processes, including recent volcanic eruptions, small seismic movements, and erosion provide key insights to the puzzle of the origin of the Galápagos Islands. Almost no other site in the world offers protection of such a complete continuum of geological and geomorphological features.	**Theme 2, 4:** Situated in the Pacific Ocean some 1,000 km from the South American continent, these 19 islands and the surrounding marine reserve have been called a unique 'living museum and showcase of evolution'. Ongoing seismic and volcanic activity reflects the processes that formed the islands. **Theme 7, 8:** The archipelago´s geology begins at the sea floor and emerges above sea level.	1978 (2001)	(vii)(viii) (ix)(x)	Natural	Ecuador	Latin America and the Caribbean
Giant's Causeway and Causeway Coast	4		The geological activity of the Cenozoic Era is clearly illustrated by the succession of the lava flows and interbasaltic beds which are in evidence on the Causeway Coast. Interpretation of the succession has allowed a detailed analysis of Tertiary events in the North Atlantic. The extremely regular columnar jointing of the Tholeiitic basalts is a spectacular feature which is displayed in exemplary fashion at the Giant's Causeway. The Causeway itself is a unique formation and a superlative horizontal section through columnar basalt lavas.	**Theme 4:** The Giant's Causeway lies at the foot of the basalt cliffs along the sea coast on the edge of the Antrim plateau in Northern Ireland. It is made up of some 40,000 massive black basalt columns sticking out of the sea. The dramatic sight has inspired legends of giants striding over the sea to Scotland. Geological studies of these formations over the last 300 years have greatly contributed to the development of the Earth sciences, and show that this striking landscape was caused by volcanic activity during the Paleogene, some 50–60 million years ago.	1986	(vii)(viii)	Natural	United Kingdom of Great Britain and Northern Ireland	Europe and North America

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Gondwana Rainforests of Australia	2	1, 3	The Gondwana Rainforests provides outstanding examples of significant ongoing geological processes. When Australia separated from Antarctica following the breakup of Gondwana, new continental margins developed. The margin which formed along Australia's eastern edge is characterised by an asymmetrical marginal swell that runs parallel to the coastline, the erosion of which has resulted in the Great Divide and the Great Escarpment. This eastern continental margin experienced volcanicity during the Cenozoic Era as the Australian continental plate moved over one of the planet's hot spots. Volcanoes erupted in sequence along the east coast resulting in the Tweed, Focal Peak, Ebor and Barrington volcanic shields. This sequence of volcanos is significant as it enables the dating of the geomorphic evolution of eastern Australia through the study of the interaction of these volcanic remnants with the eastern highlands.	**Theme 2, 1, 3:** The Gondwana Rainforests provides outstanding examples of significant ongoing geological processes. When Australia separated from Antarctica following the breakup of Gondwana, new continental margins developed. The margin which formed along Australia's eastern edge is characterised by an asymmetrical marginal swell that runs parallel to the coastline, the erosion of which has resulted in the Great Divide and the Great Escarpment.	1986 (1994)	(viii)(ix)(x)	Natural	Australia	Asia and the Pacific
Grand Canyon National Park	3	1	Within park boundaries, the geologic record spans all four eras of the Earth's evolutionary history, from the Precambrian to the Cenozoic. The Precambrian and Paleozoic portions of this record are particularly well exposed in canyon walls and include a rich fossil assemblage. Numerous caves shelter fossils and animal remains that extend the paleontological record into the Pleistocene.	**Theme 3:** Carved out by the Colorado River, the Grand Canyon (nearly 1,500 m deep) was formed during 6 million years of geologic activity and erosion by the Colorado River on the upraised Earth's crust. **Theme 1:** Its horizontal strata retrace the geological history of the past 2 billion years.	1979	(vii)(viii) (ix)(x)	Natural	United States of America	Europe and North America

Property	2021 themes (main)	2021 themes (ancillary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Great Barrier Reef	8	7	The GBR, extending 2,000 km along Queensland's coast, is a globally outstanding example of an ecosystem that has evolved over millennia. The area has been exposed and flooded by at least four glacial and interglacial cycles, and over the past 15,000 years reefs have grown on the continental shelf. During glacial periods, sea levels dropped, exposing the reefs as flat-topped hills of eroded limestone. Large rivers meandered between these hills and the coastline extended further east. During interglacial periods, rising sea levels caused the formation of continental islands, coral cays and new phases of coral growth. This environmental history can be seen in cores of old massive corals. Today the GBR forms the world's largest coral reef ecosystem, ranging from inshore fringing reefs to mid-shelf reefs, and exposed outer reefs, including examples of all stages of reef development. The processes of geological and geomorphological evolution are well represented, linking continental islands, coral cays and reefs. The varied seascapes and landscapes that occur today have been moulded by changing climates and sea levels, and the erosive power of wind and water, over long time periods. One-third of the GBR lies beyond the seaward edge of the shallower reefs; this area comprises continental slope and deep oceanic waters and abyssal plains.	**Theme 8, 7:** The GBR forms the world's largest coral reef ecosystem, ranging from inshore fringing reefs to mid-shelf reefs, and exposed outer reefs, including examples of all stages of reef development. The processes of geological and geomorphological evolution are well represented, linking continental islands, coral cays and reefs. The varied seascapes and landscapes that occur today have been moulded by changing climates and sea levels, and the erosive power of wind and water, over long time periods. One-third of the GBR lies beyond the seaward edge of the shallower reefs; this area comprises continental slope and deep oceanic waters and abyssal plains.	1981	(vii)(viii) (ix)(x)	Natural	Australia	Asia and the Pacific
Great Smoky Mountains National Park	1	3	Great Smoky Mountains National Park is of world importance as the outstanding example of the diverse Arcto-Tertiary geoflora era, providing an indication of what the late Pleistocene flora looked like before recent human impacts.	**Theme 1:** Stated to be an outstanding example of the diverse Arcto-Tertiary geoflora era, providing an indication of what the late Pleistocene flora looked like before Recent human impacts. **Theme 3:** Non-glacial, dissected, mountainous terrain.	1983	(vii)(viii) (ix)(x)	Natural	United States of America	Europe and North America

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Gros Morne National Park	2	9	The rocks of Gros Morne National Park collectively present an internationally significant illustration of the process of continental drift along the eastern coast of North America and contribute greatly to the body of knowledge and understanding of plate tectonics and the geological evolution of ancient mountain belts. In glacier-scoured highlands and spectacular fjords, glaciation has made visible the park's many geological features.	**Theme 2:** This park situated on the west coast of the island of Newfoundland provides a rare example of the process of continental drift, where deep ocean crust and the rocks of the Earth's mantle lie exposed. **Theme 9:** Pleistocene glacial action has resulted in some spectacular scenery, with coastal lowland, alpine plateau, fjords, glacial valleys, sheer cliffs, waterfalls and many pristine lakes.	1987	(vii)(viii)	Natural	Canada	Europe and North America
Gulf of Porto: Calanche of Piana, Gulf of Girolata, Scandola Reserve	7		No current retrospective Statement of OUV, but the inscription in 1983 is based on 'dramatic geological landforms', and refers to: Cycles of erosion and rejuvenation have created high cliffs of red porphyry, rhyoliths and basaltic pillars, considerably eroded by wave action. Thus the area has a varied and rugged relief on marine and shore habitats. The jagged and sheer cliffs contain many grottos and are flanked by numerous stacks and almost inaccessible islets and coves such as Tuara. The combination of the red cliffs, some 900 m high, sand beaches, headlands such as Cape Osani and the Peninsula of Elbo, and the transparent sea, make the area exceptionally beautiful.	**Theme 7:** The marine area of the property, particularly in the Scandola nature reserve, is remarkable for its wealth of algae. The terracing of living forms is very representative of the Mediterranean coastal environment: the 'pavement' of Lithophyllum (alga) leads to a bed of Posidonia which can be up to 35 m deep. Remarkable coralligenous structures form up to the edge of the continental shelf.	1983	(vii)(viii)(x)	Natural	France	Europe and North America

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Gunung Mulu National Park	6		The park is an outstanding example of major changes in the Earth's history. Three major rock formations are evident; the Mulu Formation of Paleocene and Eocene shale's, and sandstone, rising to 2,376 m at the summit of Gunung Mulu: the 1.5 km thick Melinau Limestone formation of Upper Eocene, Oligocene and Lower Miocene, rising to 1,682 m at Gunung Api; and the Miocene Setap Shale formation outcropping as a gentle line of hills to the west. Major uplift that occurred during the late Pliocene to Pleistocene is well represented in the 295 km of explored caves as a series of major cave levels. The surface and underground geomorphology and hydrology reveal significant information on the tectonic and climatic evolution of Borneo. The sequence of terrestrial alluvial deposits provides an important record of glacial – interglacial cycles with the series of uplifted caves ranging from 28 m to over 300 m above sea level are at least 2 to 3 million years old, indicating uplift rates of about 19 cm per 1,000 years.	**Theme 6:** The park has a significant area of karst in Miocene limestone that contains large underground rivers and >290 km of explored caves, including Sarawak Chamber (700 m long, 300-400 m wide and up to 100m high) – the world's largest underground room. Caves contain major speleothem deposits and 1.5 million year sediment sequences. Rich cave biota, especially notable for bats and swiftlets. Surface features include giant collapse dolines and spectacular razor-sharp pinnacle karst (ca 50 m high).	2000	(vii)(viii) (ix)(x)	Natural	Malaysia	Asia and the Pacific
Ha Long Bay	6	7	As the most extensive and best known example of marine-invaded tower karst in the world Ha Long Bay is one of the world's most important areas of Fengcong (clusters of conical peaks) and Fenglin (isolated tower features) karst. Abundant lakes, occupying drowned dolines, are one of the distinctive features of the Fencong karst, with some appearing to be tidal. Possessing a tremendous diversity of caves and other landforms derived from the unusual geomorphological process of marine invaded tower karst the caves are of three main types: remnants of phreatic caves; old karstic foot caves and marine notch caves. The property also displays the full range of karst formation processes on a very large scale and over a very long period of geological time, possessing the most complete and extensive exzample of its type in the world and providing a unique and extensive reservoir of data for the future understanding of geoclimatic history and the nature of karst processes in a complex environment.	**Theme 6, 7:** The world's most extensive and best- known example of tropical tower karst invaded by the sea. Incorporates areas of fengcong and fenglin karst.	1994 (2000)	(vii)(viii)	Natural	Viet Nam	Asia and the Pacific

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Hawaii Volcanoes National Park	4		This property is a unique example of significant island building through ongoing volcanic processes. It represents the most recent activity in the continuing process of the geologic origin and change of the Hawaiian Archipelago. The park contains significant parts of two of the world's most active and best understood volcanoes, Kilauea and Mauna Loa. The volcano Mauna Loa, measured from the ocean floor, is the greatest volcanic mass on Earth.	**Theme 4:** This property contains two of the most active volcanoes in the world, Mauna Loa (4,170 m high) and Kilauea (1,250 m high), both of which tower over the Pacific Ocean. Volcanic eruptions have created a constantly changing landscape, and the lava flows reveal surprising geological formations.	1987	(viii)	Natural	United States of America	Europe and North America
Heard and McDonald Islands	2, 4	9	The islands contain outstanding examples of significant on-going geological processes occurring in an essentially undisturbed environment, particularly physical processes which provide an understanding of the role of crustal plates in the formation of ocean basins and continents, and of atmospheric and oceanic warming. The islands are distinctive among oceanic islands in being founded upon a major submarine plateau which in this case deflects Antarctic circumpolar waters northwards, with striking consequences for geomorphological processes. They also offer an active example of plume volcanism, providing direct geological evidence of the action of the longest operational plume system known in the world. This includes information about plume interaction with overlying crustal plates, as well as insights into mantle plume composition due to the widest range of isotopic compositions of strontium, neodymium, lead and helium known from any oceanic island volcano system. Big Ben on Heard Island is the only known continuously active volcano on a sub-Antarctic island, whereas the volcano on MacDonald Island recently became active again after a 75,000 year period of dormancy, increasing significantly in size since inscription. Heard Island's relatively shallow and fast-flowing glaciers respond quickly to climate change, faster than any glaciers elsewhere, making them particularly important in monitoring climate change. They have fluctuated dramatically in recent decades and have retreated significantly.	**Theme 2, 4:** Heard Island and McDonald Islands are the only volcanically active subantarctic islands. The islands are distinctive among oceanic islands in being founded upon a major submarine plateau which in this case deflects Antarctic circumpolar waters northwards. They also offer an active example of plume volcanism, providing direct geological evidence of the action of the longest operational plume system known in the world. **Theme 9:** Heard Island's relatively shallow and fast-flowing glaciers respond quickly to climate change, faster than any glaciers elsewhere, making them particularly important in monitoring climate change. They have fluctuated dramatically in recent decades and have retreated significantly.	1997	(viii)(ix)	Natural	Australia	Asia and the Pacific

Property	2021 themes (main)	2021 themes (ancillary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
High Coast / Kvarken Archipelago	9		The High Coast/Kvarken Archipelago is of exceptional geological value for two main reasons. First, both areas have some of the highest rates of isostatic uplift in the world, meaning that the land still continues to rise in elevation following the retreat of the last inland ice sheet, with around 290 m of land uplift recorded over the past 10,500 years. The uplift is ongoing and is associated with major changes in the water bodies in post-glacial times. This phenomenon was first recognized and studied here, making the property a key area for understanding the processes of crustal response to the melting of the continental ice sheet. Second, the Kvarken Archipelago, with its 5,600 islands and surrounding sea, possesses a distinctive array of glacial depositional formations, such as De Geer moraines, which add to the variety of glacial land- and seascape features in the region. It is a global, exceptional and diverse area for studying moraine archipelagos. The High Coast and the Kvarken Archipelago represent complementary examples of post-glacial uplifting landscapes.	**Theme 9:** Both areas have some of the highest rates of isostatic uplift in the world, meaning that the land still continues to rise in elevation following the retreat of the last inland ice sheet, with around 290 m of land uplift recorded over the past 10,500 years. The uplift is ongoing and is associated with major changes in the water bodies in post-glacial times. [..] a key area for understanding the processes of crustal response to the melting of the continental ice sheet. [..] the Kvarken Archipelago, with its 5,600 islands and surrounding sea, possesses a distinctive array of glacial depositional formations, such as De Geer moraines, which add to the variety of glacial land- and seascape features in the region. It is a global, exceptional and diverse area for studying moraine archipelagos. The High Coast and the Kvarken Archipelago represent complementary examples of post-glacial uplifting landscapes.	2000 (2006)	(viii)	Natural	Finland, Sweden	Europe and North America

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Huascarán National Park	9		Huascarán is located in the High Andes and includes high plateaus of Puna grasslands, where 6,000 m peaks and glaciers form a globally notable mountainous region, including over 600 glaciers, almost 300 lakes and 41 tributaries of three important rivers: the Santa, Pativilca and Maranon. Underlying the exceptional landscape of Huascaran National Park is a broad spectrum of remarkable ongoing geological features and processes shaping the impressive geomorphology. The area's geological history and structures are very complex, with serrated peaks and the rugged topography originate from the uplifting of Mesozoic sediments, which were severely folded and faulted by complex tectonic activity at the end of the Cretaceous Period and subject to volcanism in the Pliocene and Pleistocene epochs. To this day there is strong seismic activity in the area, major earthquakes, such as in 1945, 1962 and 1970 serving as cruel reminders. Glaciation is a major element in the geomorphology and hydrology of the property. It is estimated that as much a quarter of the volume of glacial ice in the Cordillera may have disappeared since the late 1960s, a process which is likely to further change the visual face of Huascarán National Park.	**Theme 9:** Located in the High Andes and includes high plateaus of Puna grasslands, where 6,000 m peaks and glaciers form a globally notable mountainous region, including over 600 glaciers, almost 300 lakes and 41 tributaries of three important rivers: the Santa, Pativilca and Maranon	1985	(vii)(viii)	Natural	Peru	Latin America and the Caribbean
Ilulissat Icefjord	9		The Ilulissat Icefjord is an outstanding example of a stage in the Earth's history: the last ice age of the Quaternary Period. The ice-stream is one of the fastest (40 m per day) and most active in the world. Its annual calving of over 46 km3 of ice accounts for 10% of the production of all Greenland calf ice, more than any other glacier outside Antarctica. The glacier has been the object of scientific attention for 250 years and, along with its relative ease of accessibility, has significantly added to the understanding of ice-cap glaciology, climate change and related geomorphic processes.	**Theme 9:** The Ilulissat Icefjord is an outstanding example of a stage in the Earth's history: the last ice age of the Quaternary Period. The ice-stream is one of the fastest (40 m per day) and most active in the world. Its annual calving of over 46 km3 of ice accounts for 10% of the production of all Greenland calf ice, more than any other glacier outside Antarctica. [..] has significantly added to the understanding of ice-cap glaciology, climate change and related geomorphic processes.	2004	(vii)(viii)	Natural	Denmark	Europe and North America

Property	2021 themes (main)	2021 themes (ancillary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Ischigualasto / Talampaya Natural Parks	1		The property of Ischigualasto-Talampaya Natural Parks is of extraordinary scientific importance, providing a complete sequence of fossiliferous continental sediments representing the Triassic Period of geological history (c.250-200 million years before present), and revealing the evolution of vertebrate life and the nature of palaeoenvironments in the Triassic that ushered in the 'Age of the Dinosaurs'. Extending over the Ischigualasto-Villa Unión sedimentary basin, the dramatic natural landscape of the property exposes six geological formations that clearly and exceptionally document the major stage of Earth's history from the evolution from the mammal ancestors in the Early Triassic to the rise of dinosaur dominance during the Triassic. The rich diversity of fossils includes some 56 known genera and many more species of vertebrates, including but not limited to fish, amphibians and a great variety of reptiles and direct mammalian ancestors, including the early dinosaur: Eoraptor, and at least 100 species of plants together with abundant emphasis of the environments of the time. Together these remains provide a unique window on life in the Triassic Period, with many new discoveries still to be made.	**Theme 1:** Ischigualasto / Talampaya Natural Parks contain the most complete continental fossil record known from the Triassic Period (c. 250-200 million years ago). Six geological formations contain fossils of a wide range of ancestors of mammals, dinosaurs and plants revealing the evolution of vertebrates and the nature of palaeoenvironments in the Triassic Period.	2000	(viii)	Natural	Argentina	Latin America and the Caribbean
Isole Eolie (Aeolian Islands)	4		The islands' volcanic landforms represent classic features in the continuing study of volcanology world-wide. With their scientific study from at least the 18th Century, the islands have provided two of the types of eruptions (Vulcanian and Strombolian) to vulcanology and geology textbooks and so have featured prominently in the education of all geoscientists for over 200 years. They continue to provide a rich field for volcanological studies of on-going geological processes in the development of landforms.	**Theme 4:** The Aeolian Islands provide an outstanding record of volcanic island-building and destruction, and ongoing volcanic phenomena. Studied since at least the 18th century, the islands have provided the science of vulcanology with examples of two types of eruption (Vulcanian and Strombolian).	2000	(viii)	Natural	Italy	Europe and North America

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Jeju Volcanic Island and Lava Tubes	4	6	Jeju has a distinctive value as one of the few large shield volcanoes in the world built over a hot spot on a stationary continental crust plate. It is distinguished by the Geomunoreum lava tube system, which is the most impressive and significant series of protected lava tube caves in the world and includes a spectacular array of secondary carbonate speleothems (stalactites and other decorations), with an abundance and diversity unknown elsewhere within a lava cave. The Seongsan Ilchulbong tuff cone has exceptional exposures of its structural and sedimentological characteristics, making it a world-class location for understanding Surtseyan-type volcanic eruptions.	**Theme 4:** Jeju Volcanic Island and Lava Tubes includes Geomunoreum, regarded as the finest lava tube system of caves anywhere, with its multicoloured carbonate roofs and floors, and dark-coloured lava walls; the fortress-like Seongsan Ilchulbong tuff cone, rising out of the ocean, a dramatic landscape; and Mount Halla, the highest in Korea, with its waterfalls, multi-shaped rock formations, and lake-filled crater. **Theme 6:** Outstanding example of vulcanokarst, a special style of pseudokarst. This includes Geomunoreum lava tubes which are notable for spectacular decoration with carbonate speleothems, the carbonate being derived from overlying calcareous dune sands blown in from the coast.	2007	(vii)(viii)	Natural	Republic of Korea	Asia and the Pacific
Joggins Fossil Cliffs	1		Earth's history, geological and geomorphic features and processes: The 'grand exposure' of rocks at Joggins Fossil Cliffs contains the best and most complete known fossil record of terrestrial life in the iconic 'Coal Age': the Pennsylvanian Subperiod of the Carboniferous Period in Earth's history. The property bears witness to the first reptiles in Earth history, which are the earliest representatives of the amniotes, a group of animals that includes reptiles, dinosaurs, birds, and mammals. Upright fossil trees are preserved at a series of levels in the cliffs together with animal, plant and trace fossils that provide environmental context and enable a complete reconstruction to be made of the extensive fossil forests that dominated land at this time, and are now the source of most of the world's coal deposits. The property has played a vital role in the development of seminal geological and evolutionary principles, including through the work of Sir Charles Lyell and Charles Darwin, for which the site has been referred to as the 'coal age Galápagos'.	**Theme 1:** The Joggins Fossil Cliffs have been described as the 'coal age Galápagos' due to their wealth of fossils from the Carboniferous Period (c. 360 to 300 million years ago) and represent the most complete known fossil record of terrestrial life from that time.	2008	(viii)	Natural	Canada	Europe and North America

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Kluane / Wrangell-St. Elias / Glacier Bay / Tatshenshini-Alsek	9		These tectonically active joint sites feature continuous mountain building and contain outstanding examples of major ongoing geologic and glacial processes. Over 200 glaciers in the ice-covered central plateau combine to form some of the world's largest and longest glaciers, several of which stretch to the sea. The property displays a broad range of glacial processes, including world-class depositional features and classic examples of moraines, hanging valleys, and other geomorphological features.	**Theme 9:** Over 200 glaciers in the ice-covered central plateau combine to form some of the world's largest and longest glaciers, several of which stretch to the sea. The property displays a broad range of glacial processes, including world-class depositional features and classic examples of moraines, hanging valleys, and other geomorphological features.	1979 (1992, 1994)	(vii)(viii) (ix)(x)	Natural	Canada, United States of America	Europe and North America
Lake Baikal	2	5	No approved retrospective Statement of OUV. Basis of inscription is: The geological rift system which gave rise to Lake Baikal was formed in the Mesozoic Era. Lake Baikal is thus the oldest lake in the world as well as the deepest. Various tectonic forces are still on-going as evidenced in recent thermal vents in the depths of the lake.	**Theme 2:** The geological rift system which gave rise to Lake Baikal was formed in the Mesozoic Era. Various tectonic forces are still on-going as evidenced in recent thermal vents in the depths of the lake. **Theme 5:** The property includes Lake Baikal itself, the deepest in world and containing 20% of all fresh running water on the planet.	1996	(vii)(viii) (ix)(x)	Natural	Russian Federa-tion	Europe and North America
Lake Turkana National Parks	1		The geology and fossil record represents major stages of the Earth's history, including records of life represented by hominid discoveries, presence of recent geological process represented by volcanic erosional and sedimentary land forms. This property's main geological features stem from the Pliocene to Holocene epochs (c. 4 million to 10,000 years old). It has been very valuable in the reconstruction of the paleo-environment of the entire Lake Turkana Basin. The Kobi Fora deposits contain pre-human, mammalian, molluscan and other fossil remains and have contributed more to the understanding of human ancestry and paleo-environment than any other site in the world.	**Theme 1:** The Koobi Fora deposits, rich in mammalian, molluscan and other fossil remains, have contributed more to the understanding of paleo-environments than any other site on the continent.	1997 (2001)	(viii)(x)	Natural	Kenya	Africa

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Laponian Area	9		The Laponian Area contains all the processes associated with glacial activity such as U-shaped valleys, moraines, talus slopes, drumlins, presence of large erratics and rapidly flowing glacial streams. It has excellent examples of ice and frost action in a tundra setting including formation of polygons and an area of spectacularly collapsing and growing palsa mounds. Glacial rivers originating in the snowfields continue to cut through bedrock. Large unvegetated areas illustrate the phenomenon of weathering. The property also contains a record of humans being part of these ecosystems for seven thousand years.	**Theme 9:** Contains all the processes associated with glacial activity such as U-shaped valleys, moraines, talus slopes, drumlins, presence of large erratics and rapidly flowing glacial streams. It has excellent examples of ice and frost action in a tundra setting including formation of polygons and an area of spectacularly collapsing and growing palsa mounds. Glacial rivers originating in the snowfields continue to cut through bedrock.	1996	(iii)(v)(vii) (viii)(ix)	Mixed	Sweden	Europe and North America
Lena Pillars Nature Park	3	6	The Lena Pillars Nature Park displays two features of significant international interest in relation to the Earth sciences. The large cryogenically modified pillars in the region are the most notable pillar landscape of their kind known, whilst the internationally renowned and important exposures of Cambrian rocks provide a second and important supporting set of values.	**Theme 3:** Lena Pillars Nature Park is marked by spectacular rock pillars up to 100 m high that formed due to differential erosion along the banks of the Lena River. **Theme 6:** Pillars were isolated by paleo-dissolution along joints beneath thick gravel cover and are revealed along valley sides by frost processes and fluvial undercutting. Karst features include groundwater circulation and small flutes.	2012	(viii)	Natural	Russian Federa-tion	Europe and North America

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Lorentz National Park	2	6	The geology and landforms of Lorentz National Park display graphic evidence of Earth's history. Located at the meeting point of two colliding continental plates, the area has a complex geology with ongoing mountain formation as well as major sculpting by glaciation and shoreline accretion. The dominating mountain range is a direct product of the collision between the Australian and Pacific tectonic plates and the property contains the highest points of the mountains of Papua New Guinea and the only remaining glaciers on the island. There is also clear evidence of post glacial shorelines. Graphically illustrating the geomorphological effect of the last glacial and post-glacial periods, the mountains show all the classical glacial landforms including lakes and moraines. Furthermore, there are five small remnant glaciers. While all five glaciers are retreating rapidly under present climatic conditions, no other tropical glacier fields in the world exhibit glacial evolution as well as those in Lorentz National Park. There is also no better example in the world of the combined effect of collision of tectonic plates and the secondary major sculpting by glacial and post-glacial events.	**Theme 2:** The geology and landforms of Lorentz National Park display graphic evidence of Earths' history. Located at the meeting point of two colliding continental plates, the area has a complex geology with ongoing mountain formation as well as major sculpting by glaciation and shoreline accretion. The dominating mountain range is a direct product of the collision between the Australian and Pacific tectonic plates **Theme 6:** World's best example of tropical alpine glaciated karst. Extensive humid tropical karst occurs at lower elevations. Huge sinking rivers and springs.	1999	(viii)(ix)(x)	Natural	Indonesia	Asia and the Pacific
Los Glaciares National Park	9		Los Glaciares National Park is an excellent example of the significant process of glaciation, as well as of geological, geomorphic and physiographic phenomena caused by the ongoing advance and retreat of the glaciations that took place during the Pleistocene Epoch of the Quaternary Period, and the neoglaciations corresponding to the current epoch or Holocene. These events have modelled – and continue to model the landscape of the area and may be recognised by the lacustrine basins of glacial origin, the moraine systems deposited on the plateaux, or by more recent systems pertaining to the current valleys, and, the many large glacier tongues fed by the Ice Fields of the Andes. The property also provides fertile ground for scientific research on climate change.	**Theme 9:** Significant process of glaciation, as well as of geological, geomorphic and physiographic phenomena caused by the ongoing advance and retreat of the glaciations that took place during the Pleistocene Epoch of the Quaternary Period, and the neoglaciations corresponding to the current epoch or Holocene. Lacustrine basins of glacial origin, the moraine systems deposited on the plateaux, or by more recent systems pertaining to the current valleys, and, the many large glacier tongues fed by the Ice Fields of the Andes.	1981	(vii)(viii)	Natural	Argentina	Latin America and the Caribbean

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Lut Desert	10		The property represents an exceptional example of ongoing geological processes related to erosional and depositional features in a hot desert. The yardang / kalut landforms are widely considered the best-expressed in the world in terms of extent, unbroken continuity and height. The Lut sand-seas are amongst the best developed active dune fields in the world, displaying a wide variety of dune types (crescentic ridges, star dunes, complex linear dunes, funnel-shaped dunes) with dunes amongst the highest observed anywhere on our planet. Nebkha dune fields (dunes formed around plants) are widespread with those at Lut as high as any measured elsewhere. Evaporite (salt) landforms are displayed in wide variety, including white salt-crusted crystalline riverbeds, salt pans (playa) with polygonally fractured crusts, pressure-induced tepee-fractured salt crusts, gypsum domes, small salt pingos (or blisters), and salt karren. Other dry-land landforms include extensive hamada (stony desert pavements or reg) usually located on pediment surfaces with wind faceted stones (ventifacts), gullied badlands and alluvial fans (bajada).	**Theme 10:** Classic locality of yardangs developed on a massive scale, as well as gravel plains and dune fields.	2016	(vii)(viii)	Natural	Iran	Asia and the Pacific

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Macquarie Island	2, 4		Macquarie Island and its outlying islets are geologically unique in being the only place on Earth where rocks from the Earth's mantle are being actively exposed above sea level. The island is the exposed crest of the undersea Macquarie Ridge, raised to its present position where the Indo-Australian tectonic plate meets the Pacific plate. These unique exposures provide an exceptionally complete section of the structure and composition of both the oceanic crust and the upper mantle, and provide evidence of 'sea-floor spreading' and tectonic processes that have operated for hundreds of millions of years. The geological evolution of Macquarie Island began 10 million years ago and continues today with the island experiencing earthquakes and a rapid rate of uplift, all of which are related to active geological processes along the boundary between the two plates. Sequences from all crustal levels, down to 6 km below the ocean floor, are exposed as a result of tilting and differential uplift on Macquarie Island. This provides rare evidence for sequences that are common from the bottom of the oceans to the upper mantle, but not seen elsewhere in surface outcrops. The lack of deformation of this exposed crust is highly significant as it exhibits key interrelated and interdependent oceanic crustal elements in their natural relationship. Macquarie Island is the only ophiolite (a well-developed and studied geological complex) recognised to have been formed within a major ocean basin. The geology of the island is therefore considered to be the connecting link between the ophiolites of continental environments and those located within the oceanic crust.	**Theme 2:** The property is an exposure of the oceanic plate boundary between the Pacific and Australian / Indian plates, exposed with active faults and ongoing tectonic movements. **Theme 4:** Macquarie Island provides a unique example of exposure of the ocean crust of volcanic origin above the sea level and of geological evidence for sea-floor spreading.	1997	(vii)(viii)	Natural	Australia	Asia and the Pacific

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Mammoth Cave National Park	6		Mammoth Cave presents nearly every type of cave formation known. Geological processes involved in their formation continue. Today, this huge and complex network of cave passages provides a clear, complete and accessible record of the world's geomorphic and climatic changes. Outside the cave, the karst topography is superb, with fascinating landscapes and all of the classic features of a karst drainage system: vast recharge area, complex network of underground conduits, sink holes, cracks, fissures, and underground rivers and springs.	**Theme 6:** The longest cave in the world with 590 km of surveyed river passages, often large in dimension and gently sloping. The karst is developed in Lower Carboniferous (Mississippian) limestone and cave evolution commenced following uplift and exposure 3 to 4 million years ago. Extensive sinkhole plain at the surface. Large springs. Rich troglobitic fauna. The inflow margin of the karst is located beyond the park boundary.	1981	(vii)(viii)(x)	Natural	United States of America	Europe and North America
Messel Pit Fossil Site	1		Messel Pit Fossil Site is considered to be the single best site which contributes to the understanding of the Eocene, when mammals became firmly established in all principal land ecosystems. The state of preservation of its fossils is exceptional and allows for high-quality scientific work.	**Theme 1:** Messel Pit is the richest site in the world for understanding the living environment of the Eocene, between 57 million and 36 million years ago.	1995	(viii)	Natural	Germany	Europe and North America
Miguasha National Park	1		Miguasha National Park is the most outstanding fossil site in the world from the standpoint of its representation of vertebrate life and its illustration of the Devonian Period known as the Age of Fishes. The site is of paramount importance because it has the largest number and the best-preserved fossil specimens in the world of sarcopterygian fish, which gave rise to the first four-legged, air-breathing terrestrial vertebrates — the tetrapods.	**Theme 1:** Miguasha is the outstanding fossil site in the world illustrating the Devonian as the 'Age of Fishes' and displays the highest diversity in the world of the lobe-finned fishes that gave rise to the first four-legged, air-breathing terrestrial ertebrates — the tetrapods.	1999	(viii)	Natural	Canada	Europe and North America

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Mistaken Point	1		Mistaken Point fossils constitute an outstanding record of a critical milestone in the history of life on Earth, 'when life got big' after almost three billion years of microbe-dominated evolution. The fossils range in age from 580 to 560 million years, the longest continuous record of Ediacara-type megafossils anywhere, and predate by more than 40 million years the Cambrian explosion, being the oldest fossil evidence of ancestors of most modern animal groups. Mistaken Point contains the world's oldest-known examples of large, architecturally complex organisms, including soft-bodied, ancestral animals. Ecologically, Mistaken Point contains the oldest and most diverse examples of Ediacaran deep-sea communities in the world thus preserving rare insights into the ecology of these ancestral animals and the early colonization of the deep-sea floor. Other attributes contributing to the property's Outstanding Universal Value include the world's first examples of metazoan locomotion, exceptional potential for radiometric dating of the assemblages, and evidence for the role of ancient oxygen levels in the regional and global appearance of complex multicellular life.	**Theme 1:** These rugged coastal cliffs of deep marine origin date to the middle of the Ediacaran Period c. 580-560 million years ago. They record 'when life got big', the first abundant appearance of large, biologically complex organisms after three billion years of mainly microbial evolution.	2016	(viii)	Natural	Canada	Europe and North America
Monte San Giorgio	1		Monte San Giorgio is the single best known record of marine life in the Triassic period, and records important remains of life on land as well. The property has produced diverse and numerous fossils, many of which show exceptional completeness and detailed preservation. The long history of study of the property and the disciplined management of the resource have created a well documented and catalogued body of specimens of exceptional quality, and are the basis for a rich associated geological literature. As a result, Monte San Giorgio provides the principal point of reference, relevant to future discoveries of marine Triassic remains throughout the world.	**Theme 1:** Monte San Giorgio is regarded as the best fossil record of marine life from the Triassic Period (c. 250–200 million years ago)	2003 (2010)	(viii)	Natural	Italy, Switzer-land	Europe and North America

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Morne Trois Pitons National Park	4		The property encompasses extraordinary and intact examples and arrays of geomorphologic features as a result of a series of volcanic eruptions. The distinctive geology and landforms of Morne Trois Pitons National Park are comprised of three major types of geological formations: volcanic piles, glacis slopes and soufrieres. The property displays a magnificent spectrum of volcanic activity in the form of streams of various colors interspersed with fumaroles, mud ponds and hot springs, including the massive Boiling Lake. Ongoing geo-morphological processes of reduction are taking place in a largely undisturbed setting of stunning scenic value and major scientific interest.	**Theme 4:** Scenic volcanic features of great scientific interest in this national park are centered on the 1,342 m high volcano known as Morne Trois Pitons. More than 50 fumaroles, hot springs, three freshwater lakes, a 'boiling lake' and five volcanoes, located on the park's nearly 7,000 ha, together with the richest biodiversity in the Lesser Antilles.	1997	(viii)(x)	Natural	Dominica	Latin America and the Caribbean
Mosi-oa-Tunya / Victoria Falls	5	3	The Mosi-oa-Tunya / Victoria Falls and associated eight steep sided gorges have been formed through the changing waterfall positions over a geological time scale. The gorges are an outstanding example of river capture and the erosive forces of the water still continue to sculpture the hard basalts. These gorges take a zigzag course of a distance of about 150 km along the Zambezi River below the falls. Seven previous waterfalls occupied the seven gorges below the present falls, and the Devil's Cataract in Zimbabwe is the starting point for cutting back to a new waterfall. In addition, an aerial view of the falls shows possible future waterfall positions. Upstream are a spectacular series of riverine islands formed during the ongoing geological and geomorphological processes. The property is characterized by banded basalt of ancient lava flow, Kalahari sandstones and chalcedony out of which stone artefacts of Homo habilis dating three million years, stone tools of the middle Stone Age and weapons, adornments and digging tools of the late Stone Age that indicate occupation by hunter-gatherers.	**Theme 5, 3:** These are among the most spectacular waterfalls in the world. The Zambezi River, which is more than 2 km wide at this point, plunges noisily down a series of basalt gorges and raises an iridescent mist that can be seen more than 20 km away. The Mosi-oa-Tunya / Victoria Falls is the world's greatest sheet of falling water and significant worldwide for its exceptional geological and geomorphological features.	1989	(vii)(viii)	Natural	Zambia, Zimba-bwe	Africa

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Mount Etna	4		Mount Etna is one of the world's most active and iconic volcanoes, and an outstanding example of ongoing geological processes and volcanic landforms. The stratovolcano is characterized by almost continuous eruptive activity from its summit craters and fairly frequent lava flow eruptions from craters and fissures on its flanks. This exceptional volcanic activity has been documented by humans for at least 2,700 years – making it one of the world's longest documented records of historical volcanism. The diverse and accessible assemblage of volcanic features such as summit craters, cinder cones, lava flows, lava caves and the Valle de Bove depression have made Mount Etna a prime destination for research and education. Today Mount Etna is one of the best-studied and monitored volcanoes in the world, and continues to influence volcanology, geophysics and other Earth science disciplines. Mount Etna's notoriety, scientific importance, and cultural and educational value are of global significance.	**Theme 4:** Mount Etna is the highest Mediterranean island mountain and one of the most active stratovolcano in the world. The eruptive history of the volcano can be traced back 500,000 years and at least 2,700 years of this activity has been documented. The almost continuous eruptive activity of Mount Etna continues to influence volcanology, geophysics and other Earth science disciplines. The diverse and accessible range of volcanic features such as summit craters, cinder cones, lava flows and the Valle de Bove depression have made the site a prime destination for research and education.	2013	(viii)	Natural	Italy	Europe and North America
Nahanni National Park	5	3, 6	In Nahanni National Park, there is exceptional representation of on-going geological processes, notably fluvial erosion, tectonic uplift, folding and canyon development, wind erosion, karst and pseudo-karst landforms, and a variety of hot springs. The major geologic and geomorphologic features provide a combination of geological processes that are globally unique.	**Theme 5, 3:** Located along The South Nahanni River is one of the most spectacular wild rivers in North America, this park contains deep canyons and huge waterfalls. The geomorphology of the property is outstanding in its wealth of form and complexity of evolution. Fluvial processes and features predominate. Within the property are examples of almost every distinct category of river or stream that is known. Geologic and geomorphologic features include the meanders of ancient rivers, now raised high above present river levels. **Theme 6:** World's foremost example of karst development in cold climate conditions. Contains a spectacular karst landscape, including poljes, caves, and gorges, and hot spring with large tufa mound. Landscape is subject to active frost processes.	1978	(vii)(viii)	Natural	Canada	Europe and North America

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Namib Sand Sea	10		The property represents an exceptional example of ongoing geological processes involving the formation of the world's only extensive dune system in a coastal fog desert through transport of material over thousands of kilometres by river, ocean current and wind. Although the property encompasses only the Aeolian elements of this ongoing geological process, the other elements of the 'conveyor system' are assured. The diversity of the ever-changing dune formations, sculpted by pronounced daily and seasonal changes in dominant wind directions is also exceptional at a global scale within such a relatively small area.	**Theme 10:** Hosts diverse dune landscapes, representing an almost complete catalogue of dune types (star, linear, transverse, barchans), as well as other desert surface features such as interdune corridors, gravel plains, ephemeral channels and playas.	2013	(vii)(viii) (ix)(x)	Natural	Namibia	Africa
Ngorongoro Conservation Area	4	1	Ngorongoro crater is the largest unbroken caldera in the world. The crater, together with the Olmoti and Empakaai craters are part of the eastern Rift Valley, whose volcanism dates back to the late Mesozoic / early Neogene and is famous for its geology. The property also includes Laetoli and Olduvai Gorge, which contain an important palaeontological record related to human evolution.	**Theme 4:** The Ngorongoro Conservation Area spans vast expanses of highland plains, savanna, savanna woodlands and forests centerd on the spectacular Ngorongoro Crater, Africa's largest caldera. **Theme 1:** Ngorongoro has yielded a long sequence of evidence of human evolution and human-environment dynamics, including early hominid footprints dating back 3.6 million years.	1979 (2010)	(iv)(vii) (viii)(ix)(x)	Mixed	United Republic of Tanzania	Africa

Property	2021 themes (main)	2021 themes (ancillary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Papahānaumokuākea	4	2, 8	The property provides an illustrating example of island hotspot progression, formed as a result of a relatively stationary hotspot and stable tectonic plate movement. Comprising a major portion of the world's longest and oldest volcanic chain, the scale, distinctness and linearity of the manifestation of these geological processes in Papahānaumokuākea are unrivalled and have shaped our understanding of plate tectonics and hotspots. The geological values of the property are directly connected to the values in Hawai'i Volcanoes National Park and World Heritage property and jointly present a very significant testimony of hotspot volcanism.	**Theme 4, 2:** Papahānaumokuākea is a vast and isolated linear cluster of small, low lying volcanic islands and atolls, with their surrounding ocean, roughly 250 km to the northwest of the main Hawaiian Archipelago and extending over some 1,930 km. This linear cluster forms the northwest extension of the Emperor Seamount Chain. **Theme 8:** Much of the property is made up of pelagic and deepwater habitats, with notable features such as seamounts and submerged banks, extensive coral reefs, lagoons and 14 km^2 emergent lands distributed between a number of eroded high islands, pinnacles, atoll islands and cays.	2010	(iii)(vi)(viii)(ix)(x)	Mixed	United States of America	Europe and North America
Phong Nha-Ke Bang National Park	6		Phong Nha-Ke Bang National Park is part of a larger dissected plateau, which encompasses the Phong Nha, Ke Bang and Hin Namno karsts. The limestone is not continuous and demonstrates complex interbedding with shales and sandstones. This has led to a particularly distinctive topography. The caves demonstrate a discrete sequence of events, leaving behind different levels of ancient abandoned passages; evidence of major changes in the routes of underground rivers; changes in the solutional regime; deposition and later re-solution of giant speleothems and unusual features such as sub-aerial stromatolites. On the surface, there is a striking series of natural landscapes, ranging from deeply dissected ranges and plateaux to an immense polje. There is evidence of at least one period of hydrothermal activity in the evolution of this ancient mature karst system. The Son Doong Cave, first explored in 2009, could contain the world's largest cave passage in terms of diameter and continuity. The plateau is one of the finest and most distinctive examples of a complex karst landform in Southeast Asia and the property is of great importance for enhancing our understanding of the geologic, geomorphic and geo-chronological history of the region.	**Theme 6:** Extensive and complex karst development in dissected plateau environment to 1,290 m above sea level that continues across border into Laos. Long history of karst landscape evolution, possibly since early Mesozoic. Major caves and underground rivers and extensive enclosed depressions (polje).	2003 (2015)	(viii)(ix)(x)	Natural	Viet Nam	Asia and the Pacific

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Pirin National Park	9		The principal Earth science values of the property relate to its glacial geomorphology, demonstrated through a range of features including cirques, deep valleys and over 70 glacial lakes. The mountains of the property show a variety of forms and have been developed in several different rock types. Functioning natural processes allow for study of the continued evolution of the landforms of the property, and help to understand other upland areas in the region.	**Theme 9:** The principal Earth science values of the property relate to its glacial geomorphology, demonstrated through a range of features including cirques, deep valleys and over 70 glacial lakes.	1983 (2010)	(vii)(viii) (ix)	Natural	Bulgaria	Europe and North America
Pitons Management Area	4		The Pitons Management Area contains the greater part of a collapsed stratovolcano contained within the volcanic system, known to geologists as the Soufriere Volcanic Centre. Prominent within the volcanic landscape are two remnant volcanic peaks, Gros Piton and Petit Piton. The Pitons occur with a variety of other volcanic features including cumulo domes, explosion craters, pyroclastic deposits (pumice and ash), and lava flows. Collectively, these fully illustrate the volcanic history of an andesitic composite volcano associated with crustal plate subduction.	**Theme 4:** The Pitons Management Area contains a collapsed stratovolcano known as the Soufriere Volcanic Centre. Prominent within the volcanic landscape are two eroded remnants of lava domes, Gros Piton and Petit Piton, with a variety of other volcanic features including cumulo-domes, explosion craters, pyroclastic deposits (pumice and ash), and lava flows.	2004	(vii)(viii)	Natural	Saint Lucia	Latin America and the Caribbean

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Plitvice Lakes National Park	5	6	The key extraordinary process which has been shaping and continues to shape the Plitvice lake system is the tufa creation which forms barriers across the watercourse. Due to the characteristics of karst base, the waters of Plitvice Lakes are naturally supersaturated with calcium carbonate. Under certain physico-chemical and biological conditions, the dissolved calcium carbonate is deposited on the bottoms and margins of the lakes, as well as on obstacles in the water courses. Over time, this process leads to the formation of porous, simultaneously hard and fragile limestone barriers, which retain the water of creeks and rivers. The lake system is a subject to constant changes largely due to the dynamics of growth and erosion of tufa barriers. A closer look at the barriers reveals the ubiquitous remains of mosses and other terrestrial and aquatic organisms inhabiting the highly specialized habitat. The scale and intactness of the tufa formation phenomena at Plitvice Lakes amount to an outstanding example of a largely undisturbed on-going process. Extensive research on the formation, age and structure and ecological characteristics illustrate the major scientific importance of the property.	**Theme 5, 6:** International type-site for tufa-dammed lakes. Carbonate biolith barriers confine 16 lakes up to 0.8 km2 in area and up to 46 m deep. Mixed limestone and dolomitic limestone catchment area.	1979 (2000)	(vii)(viii) (ix)	Natural	Croatia	Europe and North America
Purnululu National Park	3	6	The Bungle Bungles are, by far, the most outstanding example of cone karst in sandstones anywhere in the world and owe their existence and uniqueness to several interacting geological, biological, erosional and climatic phenomena. The sandstone karst of Purnululu National Park is of great scientific importance in demonstrating so clearly the process of cone karst formation on sandstone - a phenomenon recognised by geomorphologists only recently and still not completely understood. The Bungle Bungle Ranges of the park also display to an exceptional degree evidence of geomorphic processes of dissolution, weathering and erosion in the evolution of landforms under a savannah climatic regime within an ancient, stable sedimentary landscape.	**Theme 3, 6:** Dissected sandstone platform that represents an outstanding example of quartz sandstone fluviokarst with beehive-shaped hills separated by narrow sinuous gorges.	2003	(vii)(viii)	Natural	Australia	Asia and the Pacific

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Pyrénées - Mont Perdu	9	6	The calcareous massif of Mont Perdu presents a series of classic geological landforms such as the deeply-incised canyons and spectacular cirques. The region is distinguished by its location at the tectonic collision point between the Iberian and west European plates. The property presents an exceptional geological unity, forming a calcareous massif with Mont Perdu at its centre. The resulting landscape is considerably different on the northern slopes (France) and the southern slopes (Spain).	**Theme 9:** Composed of classical geological landforms, notably deeply-incised canyons on the southern Spanish side and spectacular cirque walls on the northern slopes within France. Centred around the peak of Mont Perdu that rises to 3,348 m. **Theme 6:** Outstanding example of alpine glaciated karst to 3,352 m with extensive karrenfeld, deep canyons, deep caves and subterranean river systems. Incorporates complete karst systems.	1997 (1999)	(iii)(iv)(v) (vii)(viii)	Mixed	France, Spain	Europe and North America
Río Plátano Biosphere Reserve	5		The property comprises two main geomorphological areas. These are the steep mountain range harbouring the headwaters of Río Plátano and the flat to undulating coastal plains. The latter is composed of terraces of recent marine sediments and partly underlain by a belt of infertile deeply weathered Pleistocene quartz sandy gravels. The Río Plátano meanders for some 45 km through the lowlands forming ox-bow lakes, backwater swamps and natural levees. At about 100 m.a.s.l inland the foothills begin abruptly. The rugged granite mountains, which rise to Punta Piedra at 1,418 m.a.s.l. have many steep ridges, remarkable rock formations such as Pico Dama, a 150 m pinnacle, and many waterfalls, one reaching 150 m in height. Two thirds of the Plátano River run through a rugged part of the mountains with long stretches of white water. In one cataract in a deep forested gorge the river disappears under massive boulders. The mountains are part of the Cordillera Central, which corresponds to what was the Honduras Intercontinental Depression, during the Cretaceous Period.	**Theme 5:** The property contains nearly the full length of the Río Plátano, from its mountainous headwaters to its meanders through flat to undulating coastal plains.	1982	(vii)(viii) (ix)(x)	Natural	Honduras	Latin America and the Caribbean

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Sangay National Park	4		Sangay (a perfect cone-shaped volcano) is notable globally for its long period of continuous activity. The area exhibits a rugged topography with deep, steep-sided valleys, abundant cliffs and many rocky jagged peaks. A number of large rivers, draining eastwards into the Amazon Basin, are characterized by fast and dramatic variations in water level. Run-off is extremely rapid due to high rainfall and steep slopes. Erosion is a constant danger, although controlled by thick forest vegetation. Numerous waterfalls occur, especially in the hanging valleys of the glacial zone along the eastern edge of the Cordillera.	**Theme 4:** With its outstanding natural beauty and two active volcanoes, the park illustrates the entire spectrum of ecosystems, ranging from tropical rainforests to glaciers, with striking contrasts between the snowcapped peaks and the forests of the plains.	1983	(vii)(viii) (ix)(x)	Natural	Ecuador	Latin America and the Caribbean
Shark Bay, Western Australia	1	7	Shark Bay contains, in the hypersaline Hamelin Pool, the most diverse and abundant examples of stromatolites (hard, dome-shaped structures formed by microbial mats) in the world. Analogous structures dominated marine ecosystems on Earth for more than 3,000 million years. The stromatolites of Hamelin Pool were the first modern, living examples to be recognised that have a morphological diversity and abundance comparable to those that inhabited Proterozoic seas. As such, they are one of the world's best examples of a living analogue for the study of the nature and evolution of the Earth's biosphere up until the early Cambrian. The Wooramel Seagrass Bank is also of great geological interest due to the extensive deposit of limestone sands associated with the bank, formed by the precipitation of calcium carbonate from hypersaline waters.	**Theme 1:** Abundant stromatolites (colonies of microbes that form hard, dome-shaped deposits) that are modern representatives of some of the oldest forms of life on Earth. **Theme 7:** The Wooramel Seagrass Bank is of great geological interest due to the extensive deposit of limestone sands associated with the bank, formed by the precipitation of calcium carbonate from hypersaline waters.	1991	(vii)(viii) (ix)(x)	Natural	Australia	Asia and the Pacific

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Škocjan Caves	6		The Škocjan Caves and their surroundings are the major localities for karst topography and are the place where fundamental terms such as 'karst' and 'doline', have their origin. This is not only a strong indication of the property's importance for science, but more specifically of its importance for the history of Earth sciences. An impressive array of exceptional karst manifestations, the result of past and present geological, geomorphological, speleological and hydrological processes, are clearly at display for scientists and visitors alike within a relatively small area. The heart of the property, the main cave system with the underground stretches of the Reka River, has been formed in a thick layer of cretaceous limestone. The constantly dynamic system is an outstanding textbook example of contact Karst with well-developed features, such as a blind valley, collapsed dolines, openings, chasms and caves. Remarkably, this geological diversity supports an equally fascinating biological diversity which has important implications for land and water management.	**Theme 6:** Located in the 'classical' karst of Europe. The property comprises a sinking river at the end of blind valley, the exposed course of the underground river flowing across the base of deep collapse depressions, and a large river cave with a high canyon passage. It is representative of the input of an allogenic river into a karst system.	1986	(vii)(viii)	Natural	Slovenia	Europe and North America

Property	2021 themes (main)	2021 themes (ancillary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
South China Karst	6		The South China Karst World Heritage Property reveals the complex evolutionary history of one of the world's most outstanding landscapes. Shilin and Libo are global reference areas for the karst features and landscapes that they exhibit. The stone forests of Shilin developed over 270 million years during four major geological time periods from the Permian to present, illustrating the episodic nature of the evolution of these karst features. Libo contains carbonate outcrops of different ages shaped over millions of years by erosive processes into impressive Fengcong and Fenglin karsts. Libo also contains a combination of numerous tall karst peaks, deep dolines, sinking streams and long river caves. Wulong represents high inland karst plateaus that have experienced considerable uplift, with giant dolines and bridges. Wulong's landscapes contain evidence for the history of one of the world's great river systems, the Yangtze and its tributaries. Huanjiang Karst is an extension of the Libo Karst component. Together the two sites provide an outstanding example of fengcong karst and also preserve and display a rich diversity of surface and underground karst features. Guilin Karst is considered the best known example of continental fenglin and provides a perfect geomorphic expression of the end stage of karst evolution in South China. Guilin is a basin at a relatively low altitude and receives abundant allogenic (rainfed) water from surrounding hills, leading to a fluvial component that aids fenglin development, resulting in fenglin and fengcong karst side-by-side over a large area. Scientific study of karst development in the region has resulted in the generation of the 'Guilin model' of fengcong and fenglin karst evolution. Shibing Karst provides a spectacular fengcong landscape, which is also exceptional because it developed in relatively insoluble dolomite rocks. Shibing also contains a range of minor karst features including karren, tufa deposits and caves. Jinfoshan Karst is a unique karst table mountain surrounded by massive towering cliffs. It represents a piece of dissected plateau karst isolated from the Yunnan-Guizhou-Chonqing plateau by deep fluvial incision. An ancient planation surface remains on the summit, with an ancient weathering crust. Beneath the plateau surface are dismembered horizontal cave systems that appear at high altitude on cliff faces. Jinfoshan records the process of dissection of the high elevation karst plateau and contains evidence of the region's intermittent uplift and karstification since the Cenozoic. It is a superlative type-site of a karst table mountain.	**Theme 6:** Seven sites of a serial property that represent karst evolution in southern China. Shilin comprises stone forests on a rolling plateau in Yunnan; Jinfoshan is an isolated high plateau with huge horizontal caves suspended above deep surrounding valleys; Wulong is plateau karst with spectacular tiankeng, natural bridges deep caves and gorges; Shibing illustrates unusual cone karst development in dolomite bedrock; Libo has extensive forested cone karst (fengcong and fenglin), poljes, gorges and caves with Huanjiang being an extension of the protected area; Guilin shows the culmination of subtropical karst development with spectacular cones and towers beside the River Li. These areas provide type-sites for their principal karst features.	2007 (2014)	(vii)(viii)	Natural	China	Asia and the Pacific

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Stevns Klint	11	1	Stevns Klint is a globally exceptional testimony to the impact of meteorite impact on the history of life on Earth. The property provides a globally exceptional representation of the evidence of the Chixulub meteorite impact that took place at the end of the Cretaceous Period, c.67 million years ago. This impact is widely believed by modern scientists to have caused the end of the Age of the Dinosaurs, and led to the extinction of more than 50% of life on Earth. This is the most recent of the major mass extinctions in Earth's history. Comparative analysis indicates this is the most significant and readily accessible site, of hundreds available, to see the sedimentary record of the ash cloud formed by the meteorite impact, the actual site of the impact being deep underwater offshore the Yucatan peninsula. In addition, the property has iconic scientific importance as the most significant and accessible of the three localities where the radical theory for asteroid driven extinction was developed through the seminal work of Walter and Luis W Alvarez, with their co-workers. Stevns Klint is highly significant in terms of its past, present and future contribution to science especially pertaining to the definition of and explanation of the Cretaceous/Paleogene (K/Pg) boundary. The outstanding fossil record at Stevns Klint provides a succession of three biotic assemblages including the most diverse end-Cretaceous marine ecosystem known. The million years recorded in the rock at Stevns Klint provides evidence of a climax pre-impact community, fauna that survived a mass extinction event, and the subsequent faunal recovery and increased biodiversity following this event. The fossil record shows which taxa became extinct and which survived and reveals the tempo and mode of evolution of the succeeding post impact fauna that diversified to the marine fauna of today, thus providing important context for the main K/Pg boundary layer exposed at Stevns Klint.	**Theme 11:** Bears evidence of the asteroid impact believed to have caused the mass extinction that led to the end of the Age of the Dinosaurs. Iconic scientific importance due to its association with the radical theory for asteroid driven extinction. **Theme 1:** An exceptional fossil record is visible at the property, showing the complete succession of fauna and micro-fauna charting the recovery after the mass extinction.	2014	(viii)	Natural	Denmark	Europe and North America

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Swiss Alps Jungfrau-Aletsch	9	2	The property provides an outstanding example of the formation of the High Alps resulting from uplift and compression which began 20-40 million years ago. Within an altitude range from 809 m to 4,274 m, the region displays 400 million-year-old crystalline rocks thrust over younger carbonate rocks due to the northward drift of the African tectonic plate. Added to the dramatic record of the processes of mountain building is a great abundance and diversity of geomorphological features such as U-shaped glacial valleys, cirques, horn peaks, valley glaciers and moraines. This most glaciated part of the Alps contains the Aletsch glacier, the largest and longest in Europe, which is of significant scientific interest in the context of glacial history and ongoing processes, particularly related to climate change.	**Theme 9:** Glacial features include U-shaped glacial valleys, cirques, horn peaks, valley glaciers and moraines. This most glaciated part of the Alps contains the Aletsch glacier, the largest and longest in Europe, which is of significant scientific interest in the context of glacial history and ongoing processes, particularly related to climate change. **Theme 2:** The property provides an outstanding example of the formation of the High Alps resulting from uplift and compression which began 20-40 million years ago. Within an altitude range from 809 m to 4,274 m, the region displays 400 million-year-old crystalline rocks thrust over younger carbonate rocks due to the northward drift of the African tectonic plate.	2001 (2007)	(vii)(viii) (ix)	Natural	Switzer-land	Europe and North America
Swiss Tectonic Arena Sardona	2		Earth's history, geological and geomorphic features and processes: The Swiss Tectonic Arena Sardona provides an exceptional display of mountain building tectonics and has been recognised as a key site for geological sciences since the 18th century. The clear exposure of the Glarus Overthrust is a key, but not the only significant, feature. The exposures of the rocks below and above this feature are visible in three dimensions and, taken together, have made substantial contributions to the understanding of mountain building tectonics. Its geological features can be readily appreciated by all visitors. The property can be differentiated from other similar sites by the combination of the clear exposure of the phenomenon in a mountain setting, its history of study, and its ongoing contribution to geological sciences.	**Theme 2:** The Swiss Tectonic Arena Sardona provides an exceptional display of mountain building tectonics and has been recognised as a key site for geological sciences since the 18th century. The clear exposure of the Glarus Overthrust is a key, but not the only significant, feature. The exposures of the rocks below and above this feature are visible in three dimensions and, taken together, have made substantial contributions to the understanding of mountain building tectonics	2008	(viii)	Natural	Switzer-land	Europe and North America

Property	2021 themes (main)	2021 themes (ancillary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Tajik National Park (Mountains of the Pamirs)	9	2, 5	The Pamir Mountains are a major centre of glaciation on the Eurasian continent and Tajik National Park illustrates within one protected area an outstanding juxtaposition of many high mountains, valley glaciers, and deep river gorges alongside the cold continental desert environment of the high Pamir Plateau landforms. An outstanding landform feature of the property's geologically dynamic terrain is Lake Sarez. It was created by an earthquake-generated landslide of an estimated six billion tonnes of material and is possibly the youngest deep water alpine lake in the world. It is of international scientific and geomorphological hazard significance because of the on-going geological processes influencing its stability, and the sort of lacustrine ecosystem which will develop over time. Tajik National Park furthermore offers a unique opportunity for the study of plate tectonics and continental subduction phenomena thereby contributing to our fundamental understanding of Earth building processes.	**Theme 9:** The Pamir Mountains are a major centre of glaciation on the Eurasian continent and Tajik National Park illustrates within one protected area an outstanding juxtaposition of many high mountains, valley glaciers, and deep river gorges alongside the cold continental desert environment of the high Pamir Plateau landforms. **Theme 2:** Tajik National Park offers a unique opportunity for the study of plate tectonics and continental subduction phenomena thereby contributing to our fundamental understanding of Earth building processes. **Theme 5:** An outstanding landform feature of the property's geologically dynamic terrain is Lake Sarez. It was created by an earthquake-generated landslide of an estimated six billion tonnes of material and is possibly the youngest deep water alpine lake in the world. It is of international scientific and geomorphological hazard significance because of the on-going geological processes influencing its stability, and the sort of lacustrine ecosystem which will develop over time.	2013	(vii)(viii)	Natural	Tajikistan	Asia and the Pacific
Talamanca Range-La Amistad Reserves / La Amistad National Park	9		The Talamanca Range is a very particular sample of the recent geological history of the Central American Isthmus, the relatively narrow strip of land connecting North and South America and separating the Pacific and Atlantic Oceans. The property shows impressive marks of Quaternary glacial activity, which has shaped glacial cirques, glacial lakes and deep, U-shaped valleys, which cannot be found anywhere else in Central America.	**Theme 9:** Quaternary glacial activity has shaped glacial cirques, glacial lakes and deep, U-shaped valleys, that cannot be found anywhere else in Central America.	1983 (1990)	(vii)(viii) (ix)(x)	Natural	Costa Rica, Panama	Latin America and the Caribbean

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Tasmanian Wilderness	9	1	No current retrospective statement of OUV. The contemporary inscription is based on the following Earth science values: Rock formations, glacial deposits, extraglacial processes and glacio-karst landforms of his property provide a record of major stages of Earth's history, and together with the associated ecology, provide living evidence of the previous existence of the southern supercontinent of Gondwana and its subsequent fragmentation. The associated processes are occurring at large scale in a variety of undisturbed environments, providing a benchmark against which the effects of human activities can be measured.	**Theme 9, 1:** Rock formations, glacial deposits, extraglacial processes and glacio-karst landforms of his property provide a record of major stages of Earth's history, and together with the associated ecology, provide living evidence of the previous existence of the southern supercontinent of Gondwana and its subsequent fragmentation.	1982 (1990)	(iii)(iv)(vi) (vii)(viii) (ix)(x)	Mixed	Australia	Asia and the Pacific
Tassili n'Ajjer	3		The geological conformation of Tassili n'Ajjer includes Precambrian crystalline elements and sedimentary sandstone successions of great paleo-geographical and paleo-ecological interest.	**Theme 3:** Sandstone plateaus and escarpments that are highly dissected with a range of erosional features.	1982	(i)(iii)(vii) (viii)	Mixed	Algeria	Arab States

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Te Wahipounamu – South West New Zealand	9	1, 2	Te Wähipounamu - South West New Zealand is considered to be the best modern example of the primitive taxa of Gondwanaland seen in modern ecosystems – and as such the property is of global significance. The progressive break-up of the southern super-continent of Gondwanaland is considered one of the most important events in the Earth's evolutionary history. New Zealand's separation before the appearance of marsupials and other mammals, and its long isolation since, were key factors enabling the survival of the ancient Gondwanan biota on the islands of New Zealand to a greater degree than elsewhere. The living representatives of this ancient biota include flightless kiwis, carnivorous land snails, 14 species of podocarp and genera or beech. The South West is also an outstanding example of the impact of the Pleistocene epoch of Earth history. Ice-carved landforms created by these 'Ice Age' glaciers dominate the mountain lands, and are especially well-preserved in the harder, plutonic igneous rocks of Fiordland. Glacier-cut fiords, lakes, deep U-shaped valleys, hanging valleys, cirques, and ice-shorn spurs are graphic illustrations of the powerful influence of these glaciers on the landscape. Depositional landforms of Pleistocene glacial origin are also important, especially in Westland, west of the Alpine Fault. Chronological sequences of outwash gravels, and moraine ridges in elegant curves and loops, outline the shapes of both former piedmont glaciers and Holocene "post-glacial" valley glaciers.	**Theme 9:** South-west New Zealand is also an outstanding example of the impact of the Pleistocene epoch of Earth history. Ice-carved landforms created by these 'Ice Age' glaciers dominate the mountain lands, and are especially well-preserved in the harder, plutonic igneous rocks of Fiordland. Glacier-cut fiords, lakes, deep U-shaped valleys, hanging valleys, cirques, and ice-shorn spurs are graphic illustrations of the powerful influence of these glaciers on the landscape. Depositional landforms of Pleistocene glacial origin are also important, especially in Westland, west of the Alpine Fault. Chronological sequences of outwash gravels, and moraine ridges in elegant curves and loops, outline the shapes of both former piedmont glaciers and Holocene 'post-glacial' valley glaciers. **Theme 1, 2:** The progressive break-up of the southern super-continent of Gondwana is considered one of the most important events in the Earth's evolutionary history. New Zealand's separation before the appearance of marsupials and other mammals, and its long isolation since, were key factors enabling the survival of the ancient Gondwanan biota on the islands of New Zealand to a greater degree than elsewhere.	1990	(vii)(viii) (ix)(x)	Natural	New Zealand	Asia and the Pacific

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Teide National Park	4		Teide National Park is an exceptional example of a relatively old, slow moving, geologically complex and mature volcanic system. It is of global importance in providing diverse evidence of the geological processes that underpin the evolution of oceanic islands, and these values complement those of existing volcanic properties on the World Heritage List, such as the Hawaii Volcanoes National Park. It offers a diverse and accessible assemblage of volcanic features and landscapes in a relatively limited area. The area is a major centre for international research with a long history of influence on geology and geomorphology especially through the work of von Humboldt, von Buch and Lyell, which has made Mount Teide a significant site in the history of volcanology.	**Theme 4:** Teide National Park features the Teide-Pico Viejo stratovolcano that, at 3,718 m, is the highest peak on Spanish soil. Rising 7,500 m above the ocean floor, it is regarded as the world's third-tallest volcanic structure and stands in the Las Canadas caldera. Teide is of global importance in providing evidence of the geological processes that underpin the evolution of oceanic islands.	2007	(vii)(viii)	Natural	Spain	Europe and North America
The Dolomites	3	1	The Dolomites are of international significance for geomorphology, as the classic site for the development of mountains in dolomitic limestone. The area presents a wide range of landforms related to erosion, tectonism and glaciation. The quantity and concentration of extremely varied limestone formations is extraordinary in a global context, including peaks, towers, pinnacles and some of the highest vertical rock walls in the world. The geological values are also of international significance, notably the evidence of Mesozoic carbonate platforms, or 'fossilized atolls', particularly in terms of the evidence they provide of the evolution of the bio-constructors after the Permian/Triassic boundary, and the preservation of the relationships between the reefs they constructed and their surrounding basins. The Dolomites also include several internationally important type sections for the stratigraphy of the Triassic Period. The scientific values of the property are also supported by the evidence of a long history of study and recognition at the international level. Taken together, the combination of geomorphological and geological values creates a property of global significance.	**Theme 3:** Rock-controlled cliffs and plateaus, with additional role of glaciation. **Theme 1:** The Dolomites contain an outstanding record of Triassic reef systems and their biotas.	2009	(vii)(viii)	Natural	Italy	Europe and North America

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Three Parallel Rivers of Yunnan Protected Areas	2	3, 5	The property is of outstanding value for displaying the geological history of the last 50 million years associated with the collision of the Indian Plate with the Eurasian Plate, the closure of the ancient Tethys Sea, and the uplifting of the Himalaya Range and the Tibetan Plateau. These were major geological events in the evolution of the land surface of Asia and they are on-going. The diverse rock types within the property record this history and, in addition, the range of karst, granite monolith, and Danxia sandstone landforms in the alpine zone include some of the best of their type in the mountains of the world.	**Theme 2:** The property is of outstanding value for displaying the geological history of the last 50 million years associated with the collision of the Indian Plate with the Eurasian Plate, the closure of the ancient Tethys Sea, and the uplifting of the Himalaya Range and the Tibetan Plateau. **Themes 3, 5:** Deeply carved valleys of major rivers that pass through steep gorges which, in places, are 3,000 m deep and are bordered by glaciated peaks more than 6,000 m high.	2003	(vii)(viii) (ix)(x)	Natural	China	Asia and the Pacific
Tongariro National Park	4		No approved retrospective Statement of OUV. Basis of inscription are: Earth's Evolutionary History - The park lies at the south-western terminus of a Pacific chain of volcanoes aligned along a major tectonic plate boundary. Ongoing geological processes - The park's volcanoes contain a complete range of volcanic features	**Theme 4:** Tongariro National Park includes three active volcanoes, which have cultural and religious significance for the Maori people and symbolize the spiritual links between this community and its environment.	1990 (1993)	(vi)(vii) (viii)	Mixed	New Zealand	Asia and the Pacific

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Trang An Landscape Complex	6		Trang An is a superb geological property that displays, in a globally exceptional way, the final stages of tower-karst landscape evolution in a humid tropical environment. Deep dissection of an uplifted limestone massif over a period of five million years has produced a series of classical karst landforms, including cones, towers, enclosed depressions (cockpits), interior-draining valleys (poljes), foot-caves and subterranean cave passages decorated with speleothems. The presence of transitional forms between 'fengcong' karst with ridges connecting towers, and 'fenglin' karst where towers stand isolated on alluvial plains, is an extremely significant feature of the property. Trang An is an unusual autogenic karst system, being rain-fed only and hydrologically isolated from rivers in the surrounding terrain. Former inundation by the sea transformed the massif into an archipelago for some periods, though it is fully emergent on land today. Fluctuations of sea level are evidenced by an altitudinal series of erosion notches in cliffs, with associated caves, wave-cut platforms, beach deposits and marine shell layers.	**Theme 6:** Tower karst in its end stages near sea level. Numerous navigable foot-caves, and extensive swamp notch and marine notch development reflecting sea level changes.	2014	(v)(vii)(viii)	Mixed	Viet Nam	Asia and the Pacific

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Uluṟu-Kata Tjuṯa National Park	3		No current retrospective Statement of OUV, but the following text related to criterion (viii) has been developed previously as a draft that will likely be considered in the future, based on the date of inscription: The inselbergs (steep-sided isolated hills rising abruptly from the Earth) of Uluṟu and Kata Tjuṯa are outstanding examples of tectonic, geochemical and geomorphic processes. Uluṟu and Kata Tjuṯa are striking examples of geological and erosional processes over time and they reflect the age, and relatively stable nature, of the Australian continent. Such stability at the continental level is globally rare. The geology of Uluṟu and Kata Tjuṯa demonstrate ongoing geological processes of remarkable interest. The sides of Uluṟu are marked by a number of unusual features which can be ascribed to differing processes of erosion. For example, the feature known as ngaltawata, a ceremonial pole associated with Mala Tjukurpa, is ascribed to sheeting of massive rock parallel to the existing surface. During rain periods, the runoff from Uluṟu cascades down the fissures forming waterfalls, some up to 100 metres high. Caves at the base of Uluṟu are formed by a widespread arid zone process of granular disintegration known as cavernous weathering.	**Theme 3:** This park features inselbergs of sandstone (Uluṟu) and conglomerate (Kata Tjuṯa) that rise spectactacularly above the vast red sandy plain of central Australia.	1987 (1994)	(v)(vi)(vii) (viii)	Mixed	Australia	Asia and the Pacific
Vallée de Mai Nature Reserve	1		Shaped by geological and biological processes that took place millions of years ago, the property is an outstanding example of an earlier and major stage in the evolutionary history of the world's flora. Its ecology is dominated by endemic palms, and especially by the coco-de-mer, famous for its distinctively large double nut containing the largest seed in the plant kingdom. The Vallée de Mai constitutes a living laboratory, illustrating of what other tropical areas would have been before the advent of more advanced plant families.	**Theme 1:** Stated to constitute a living laboratory, illustrating of what other tropical areas would have been before the advent of more advanced plant families.	1983	(vii)(viii) (ix)(x)	Natural	Sey-chelles	Africa

Property	2021 themes (main)	2021 themes (ancil-lary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Vatnajökull National Park - Dynamic Nature of Fire and Ice	4, 9		The coexistence and ongoing interaction of an active oceanic rift on land, a mantle plume, the atmosphere and an ice cap, which has varied in size and extent over the past 2.8 million years, make the property unique in a global context. Earth system interactions are constantly building and reshaping the property, creating remarkably diverse landscapes and a wide variety of tectonic, volcanic and glaciovolcanic features. Especially interesting and unique in this regard are the basaltic lava shields (Iceland shields), volcanic fissures and cone rows, vast flood lavas, and features of ice dominant glacio-volcanism, such as tuyas and tindar. Interestingly, the well exposed volcanic features of the property have been used as analogues for similar features on the planet Mars. Geothermal heat and subglacial eruptions produce meltwater and jökulhlaups that maintain globally unique sandur plains, to the north and south of the Vatnajökull ice cap, as well as rapidly evolving canyons. In addition, the property contains a dynamic array of glacial- and geomorphological features, created by expanding or retreating glaciers responding to changes in climate. These features can be easily accessed and explored at the snouts of Vatnajökull's many outlet glaciers and their forelands, especially in the southern lowlands, making the property a flagship glacial research location.	**Theme 4, 9:** This is an iconic volcanic region that also features the continental drifting currently active in this part of Atlantic Ocean with ten central volcanoes, eight of which are subglacial. Two of these are among the most active in Iceland. The interaction between volcanoes and the rifts that underlie the Vatnajökull ice cap takes many forms, the most spectacular of which is the jökulhlaup – a sudden flood caused by the breach of the margin of a glacier during an eruption.	2019	(viii)	Natural	Iceland	Europe and North America

Property	2021 themes (main)	2021 themes (ancillary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Virunga National Park	4		Virunga National Park is located in the centre of the Albertine Rift, of the Great Rift Valley. In the southern part of the park, tectonic activity due to the extension of the Earth's crust in this region has caused the emergence of the Virunga massif, comprising eight volcanoes, seven of which are located, totally or partially, in the park. Among them, are the two most active volcanoes of Africa – Nyamuragira and nearby Nyiragongo – which between them are responsible for two-fifths of the historic volcanic eruptions on the African continent and which are characterized by the extreme fluidity of the alkaline lava. The activity of Nyiragongo is of world importance as a witness to volcanism of a lava lake: the bottom of its crater is in fact filled by a lake of quasi permanent lava that empties periodically with catastrophic consequences for the local communities. The northern sector of the park includes about 20% of the massif of Monts Rwenzori – the largest glacial region of Africa and the only true alpine mountain chain of the continent. It borders the Rwenzori Mountains National Park of Uganda, inscribed as World Heritage, with which it shares the 'Pic Marguerite', third highest summit of Africa (5,109 m).	**Theme 4:** The Virunga massif comprises eight volcanoes, seven of which are located, totally or partially, in the park. Among them, are the two most active volcanoes of Africa – Nyamuragira and nearby Nyiragongo – which between them are responsible for two-fifths of the historic volcanic eruptions on the African continent and which are characterized by the extreme fluidity of the alkaline lava. The activity of Nyiragongo is of world importance as a witness to volcanism of a lava lake: the bottom of its crater is in fact filled by a lake of quasi permanent lava that empties periodically with catastrophic consequences for the local communities.	1979	(vii)(viii)(x)	Natural	Democratic Republic of the Congo	Africa
Volcanoes of Kamchatka	4		The addition of Kluchevskoy Nature Park as the sixth component of the property further adds to the overall coverage of the range of Kamchatka's natural features. The addition to the site clearly meets criterion (viii) in its own right as an outstanding example of geological processes and landforms and therefore contributes in a very significant way to the expanded property as a whole meeting criterion (viii).	**Theme 4:** One of the most outstanding volcanic regions in the world, with a high density of active volcanoes, a variety of types, and a wide range of related features. The six sites included in the serial property group together the majority of volcanic features of the Kamchatka peninsula. The interplay of active volcanoes and glaciers forms a dynamic landscape of great beauty.	1996 (2001)	(vii)(viii)(ix)(x)	Natural	Russian Federation	Europe and North America

Property	2021 themes (main)	2021 themes (ancillary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Vredefort Dome	11		Vredefort Dome is the oldest, largest, and most deeply eroded complex meteorite impact structure in the world. It is the site of the world's greatest single, known energy release event. It contains high quality and accessible geological (outcrop) sites, which demonstrate a range of geological evidences of a complex meteorite impact structure. The rural and natural landscapes of the serial property help portray the magnitude of the ring structures resulting from the impact. The serial property is considered to be a representative sample of a complex meteorite impact structure. A comprehensive comparative analysis with other complex meteorite impact structures demonstrated that it is the only example on Earth providing a full geological profile of an astrobleme below the crater floor, thereby enabling research into the genesis and development of an astrobleme immediately post impact.	**Theme 11:** The oldest, largest, and most deeply eroded complex meteorite impact structure in the world. The site of the world's greatest single, known energy release event.	2005	(viii)	Natural	South Africa	Africa
Wadden Sea	7		The Wadden Sea is a depositional coastline of unparalleled scale and diversity. It is distinctive in being almost entirely a tidal flat and barrier system with only minor river influences, and an outstanding example of the large-scale development of an intricate and complex temperate-climate sandy barrier coast under conditions of rising sea-level. Highly dynamic natural processes are uninterrupted across the vast majority of the property, creating a variety of different barrier islands, channels, flats, gullies, saltmarshes and other coastal and sedimentary features.	**Theme 7:** The largest unbroken system of intertidal sand and mud flats in the world.	2009 (2014)	(viii)(ix)(x)	Natural	Denmark, Germany, Netherlands	Europe and North America
Wadi Al-Hitan (Whale Valley)	1		Wadi Al-Hitan is the most important site in the world to demonstrate one of the iconic changes that make up the record of life on Earth: the evolution of the whales. It portrays vividly their form and mode of life during their transition from land animals to a marine existence. It exceeds the values of other comparable sites in terms of the number, concentration and quality of its fossils, and their accessibility and setting in an attractive and protected landscape.	**Theme 1:** Wadi Al-Hitan is the most important site in the world to demonstrate one of the iconic changes that make up the record of life on Earth: the evolution of the whales during their transition from land animals to a marine existence.	2005	(viii)	Natural	Egypt	Arab States

Property	2021 themes (main)	2021 themes (ancillary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
West Norwegian Fjords – Geirangerfjord and Nærøyfjord	9		The West Norwegian Fjords are classic, superbly developed fjords, considered as the type locality for fjord landscapes in the world. They are comparable in scale and quality to other existing fjords on the World Heritage List and are distinguished by the climate and geological setting. The property displays a full range of the inner segments of two of the world's longest and deepest fjords, and provides well-developed examples of young, active glaciation during the Pleistocene ice age. The ice- and wave-polished surfaces of the steep fjord sides provide superbly exposed and continuous three-dimensional sections through the bedrock. The record of the postglacial isostatic rebound of the crust and its geomorphic expression in the fjord landscape are significant, and represent key areas for the scientific study of slope instability and the resulting geohazards.	**Theme 9:** The property displays a full range of the inner segments of two of the world's longest and deepest fjords, and provides well-developed examples of young, active glaciation during the Pleistocene ice age. The ice- and wave-polished surfaces of the steep fjord sides provide superbly exposed and continuous three-dimensional sections through the bedrock. The record of the postglacial isostatic rebound of the crust and its geomorphic expression in the fjord landscape are significant, and represent key areas for the scientific study of slope instability and the resulting geohazards.	2005	(vii)(viii)	Natural	Norway	Europe and North America
Wet Tropics of Queensland	1		The Wet Tropics contains one of the most complete and diverse living records of the major stages in the evolution of land plants, from the very first pteridophytes more than 200 million years ago to the evolution of seed-producing plants including the cone-bearing cycads and southern conifers (gymnosperms), followed by the flowering plants (angiosperms). As the Wet Tropics is the largest part of the entire Australasian region where rainforests have persisted continuously since Gondwanan times, its living flora, with the highest concentration of primitive, archaic and relict taxa known, is the closest modern-day counterpart for Gondwanan forests. In addition, all of Australia's unique marsupials and most of its other animals originated in rainforest ecosystems, and the Wet Tropics still contains many of their closest surviving members. This makes it one of the most important living records of the history of marsupials, as well as of songbirds.	**Theme 1:** The living plants in this property are stated to represent 'major stages in the evolution of land plants, from the very first land plants to higher plants (Gymnosperms and Angiosperms)'.	1988	(vii)(viii) (ix)(x)	Natural	Australia	Asia and the Pacific

Property	2021 themes (main)	2021 themes (ancillary)	Justification under criterion (viii)	Relationship to identified themes	Date inscribed (extension)	Criteria	Category	State	Region
Willandra Lakes Region	5	1	The Australian geological environment, with its low topographic relief and low energy systems, is unique in the longevity of the landscapes it preserves, and the Willandra Lakes provides an exceptional window into climatic and related environmental changes over the last 100,000 years. The Willandra Lakes, largely unmodified since they dried out some 18,500 years BP, provide excellent conditions for recording the events of the Pleistocene Epoch, and demonstrate how non-glaciated zones responded to the major glacial-interglacial fluctuations. The demonstration at this property of the close interconnection between landforms and pedogenesis, palaeochemistry, climatology, archaeology, archaeomagnetism, radiocarbon dating, palaeoecology and faunal extinction, represents a classic landmark in Pleistocene research in the Australasian area. Willandra Lakes Region is also of exceptional importance for investigating the period when humans became dominant in Australia, and the large species of wildlife became extinct, and research continues to elucidate what role humans played in these events.	**Theme 5, 1:** Willandra Lakes provides an exceptional window into climatic and related environmental changes over the last 100,000 years, a period of major climatic changes when humans became dominant in Australia and large species of wildlife became extinct.	1981	(iii)(viii)	Mixed	Australia	Asia and the Pacific
Yellowstone National Park	4		Yellowstone is one of the world's foremost sites for the study and appreciation of the evolutionary history of the Earth. The park has a globally unparalleled assemblage of surficial geothermal activity, thousands of hot springs, mudpots and fumaroles, and more than half of the world's active geysers. Nearly 150 species of fossil plants, ranging from small ferns and rushes up to large Sequoia and many other tree species, have been identified in the park's abundant fossil deposits. The world's largest recognized caldera (45 km by 75 km – 27 miles by 45 miles) is contained within the park.	**Theme 4:** Yellowstone National Park is the world's first national park, set aside to preserve a wide variety of young volcanic and related hydrothermal features. Yellowstone contains half of all the world's known geothermal features, with more than 10,000 examples. It also has the world's largest concentration of geysers (more than 300 geysers, or two thirds of all those on the planet).	1978	(vii)(viii) (ix)(x)	Natural	United States of America	Europe and North America
Yosemite National Park	9		Glacial action combined with the granitic bedrock has produced unique and pronounced landform features including distinctive polished dome structures, as well as hanging valleys, tarns, moraines and U-shaped valleys. Granitic landforms such as Half Dome and the vertical walls of El Capitan are classic distinctive reflections of geologic history. No other area portrays the effects of glaciation on underlying granitic domes as well as Yosemite does.	**Theme 9:** Glacial action combined with the granitic bedrock has produced unique and pronounced landform features including distinctive polished dome structures, as well as hanging valleys, tarns, moraines and U-shaped valleys.	1984	(vii)(viii)	Natural	United States of America	Europe and North America

Annex 2: Contextual framework for World Heritage fossil properties

RECOMMENDATION 1
Choose sites that contain well-preserved fossil accumulations of high species diversity which in combination best document the story of community and environmental change through time.

RECOMMENDATION 2
The 'events' to be represented in the history of life should, where possible, encompass the iconography of a tree of life not a ladder of progress.

RECOMMENDATION 3
Choose fossil Lagerstatten and make provision for expanding the List or substituting sites/fossils to better tell any chapter of the story.

RECOMMENDATION 4
Separate Precambrian history from Phanerozoic history (the roots from the upper branches of the evolutionary tree respectively),
Present Precambrian history as major events, such as the origin of life, multicellularity, etc. and
Present Phanerozoic history in terms of communities and/or stages in the evolution of major groups .

RECOMMENDATION 6
Phanerozoic sites should be chosen so as to be representative in time and space of both community structure and selected phylogenetic lineages.

RECOMMENDATION 7
Any fossil Lagerstatten chosen from the Phanerozoic should wherever possible be of high diversity and include significant invertebrate as well as vertebrate assemblages.

RECOMMENDATION 8
A condition for granting World Heritage status should make provision for curation, study and display of any site/fossils.

RECOMMENDATION 9
Specialists in the major Phanerozoic groups and time periods should be consulted to refine and update the indicative list. This may be best achieved through a panel drawn from the international palaeontological societies.

From: **Wells, 1996, p. 40-41**

Annex 3: IUCN fossil site evaluation checklist

IUCN fossil site evaluation checklist

1. *Does the site provide fossils which cover an extended period of geological time: i.e. how wide is the geological window?*
2. *Does the site provide specimens of a limited number of species or whole biotic assemblages: i.e. how rich is the species diversity?*
3. *How unique is the site in yielding fossil specimens for that particular period of geological time: i.e. would this be the 'type locality' for study or are there similar areas that are alternatives?*
4. *Are there comparable sites elsewhere that contribute to the understanding of the total 'story' of that point in time/space: i.e. is a single site nomination sufficient or should a serial nomination be considered?*
5. *Is the site the only main location where major scientific advances were (or are) being made that have made a substantial contribution to the understanding of life on Earth?*
6. *What are the prospects for ongoing discoveries at the site?*
7. *How international is the level of interest in the site?*
8. *Are there other features of natural value (e.g. scenery, landform, vegetation) associated with the site: i.e. does there exist within the adjacent area modern geological or biological processes that relate to the fossil resource?*
9. *What is the state of preservation of specimens yielded from the site?*
10. *Do the fossils yielded provide an understanding of the conservation status of contemporary taxa and/or communities: i.e. how relevant is the site in documenting the consequences to modern biota of gradual change through time?*

Source: Wells (1996).

From: *Preparing World Heritage Nominations*, **UNESCO World Heritage Centre (2011, p. 42)**

Annex 4: Distribution of karstifiable rocks and potential karst aquifers across the world

With permission from Goldscheider et al. (2020), red triangles on Figure 18 depicting the locations of World Heritage Properties with karst OUV, their numbers referring to the list of World Heritage karst sites.

No.	State Party	World Heritage Property	Inscribed (extended)	Criteria	Key Karst Features	Environmental context
5*	Australia	Purnululu	2003	vii,viii	Outstanding example of quartz sandstone fluviokarst with beehive-shaped hills separated by narrow sinuous gorges. Developed on rocks of Devonian age.	Tropical savannah regime.
9*	Canada	Nahanni National Park	1978	vii,viii	World's foremost example of karst development in cold climate conditions. Contains a spectacular karst landscape, including poljes, caves, and gorges, and hot spring with large tufa mound. Landscape is subject to active frost processes.	Cold continental climate with wide monthly variations in temperature and precipitation. Alpine tundra and mountainous taiga environments with discontinuous permafrost. Rich diversity of vegetation and wildlife.
10*	Canada	Canadian Rocky Mountain Parks	1984 (1990)	vii,viii	Includes large areas of limestones and dolomites. Outstanding example of glaciokarst terrain. Many karren, subterranean streams, springs and caves. Columbia Icefield partly overlies and intrudes Castleguard Cave.	Located across continental divide between 1036 m to 3954 m. Continental cool temperate alpine climate with mountain permafrost. Rich diversity of vegetation and wildlife.
11*	China	Huanglong	1992	vii	Hot springs emerging from carbonate rocks have precipitated extensive calcareous travertine deposits along valley floor with numerous rimstone pools. Represents depositional output landforms of deeply circulating karst groundwater system.	Warm temperate continental alpine environment. Forested valleys surrounded by mountains to 5000 m.
12*	China	Jiuzhaigou Valley	1992	vii	Extensive areas of limestone and dolomite. Carbonate tufa deposits from cold springs have formed a series of tufa-dammed lakes and tufa-coated cascades along valley floor. Represents depositional output landforms of shallow karst groundwater system with significant epikarst water contribution.	Warm temperate continental alpine environment. Forested valleys surrounded by mountains to 4800 m.

No.	State Party	World Heritage Property	Inscribed (extended)	Criteria	Key Karst Features	Environmental context
13*	China	Wulingyuan Scenic and Historic Interest Area	1992	vii	A mixed quartz sandstone (66%) and limestone (33%) area, most notable for 3100 sandstone pillars and peaks to 200 m high separated by ravines and gorges. Limestone part contains about 40 known caves with rich decoration and two natural bridges, one of which is 357m. high. Includes entire Suoxi karst catchment. Particularly outstanding for its spectacular sandstone fluviokarst relief.	Humid warm temperate climate with deciduous forest. Altitude range 450 m to 1264 m.
15*	China	South China Karst	2007 (2014)	vii, viii	Seven sites of a serial nomination that represent karst evolution in southern China. Shilin comprises stone forests on a rolling plateau in Yunnan; Jinfoshan is an isolated high plateau with huge horizontal caves suspended above deep surrounding valleys; Wulong is plateau karst with spectacular tiankeng, natural bridges deep caves and gorges; Shibing illustrates unusual cone karst development in dolomite bedrock; Libo has extensive forested cone karst (fengcong and fenglin), poljes, gorges and caves with Huanjiang being an extension of the protected area; Guilin shows the culmination of subtropical karst development with spectacular cones and towers beside the River Li. These areas provide typesites for their principal karst features.	Continental humid subtropical plateau (Shilin, Jinfoshan, Wulong) to subtropical monsoonal (Shibing, Libo, Huanjiang, Guilin). Extensive natural forest cover at Libo-Huanjiang.
16*	Croatia	Plitvice Lakes National Park	1979 (2000)	vii,viii, ix	International type-site for tufa-dammed lakes. Carbonate biolith barriers confine 16 lakes up to 0.8 km^2 in area and up to 46 m deep. Mixed limestone and dolomitic limestone catchment area.	Continental humid warm temperate. Mixed coniferous and deciduous forested catchment.
22*	France/ Spain	Pyrénées - Mont Perdu	1997 (1999)	iii, iv, v, vii, viii	Outstanding example of alpine glaciated karst to 3352 m with extensive karrenfeld, deep canyons, deep caves and subterranean river systems. Incorporates complete karst systems.	Humid maritime alpine climate to north and drier Mediterranean climate to south with associated complex vegetation zonation.
23*	Greece	Meteora	1988	i,ii,iv,v,vii	Sheer towers and pillars 10 to >100 m high developed in early Tertiary deltaic quartz conglomerate often fluted with closely spaced vertical karren (the towers support almost inaccessible monastery buildings). Fluviokarst.	Mean altitude 300 m rising to 1000 m. Mediterranean climate.
24*	Hungary/ Slovakia	Caves of Aggtelek Karst and Slovak Karst	1995 (2000)	viii	Area contains 712 caves. Variety of cave types, including Dobšinská Ice Cave, and speleothem forms with stalagmites to 32.7 m high. Surface landscape is a temperate doline karst with some evidence of a prior humid tropical or subtropical influence, which has evolved intermittently since the Cretaceous.	Continental humid temperate.

Annex 4: Distribution of karstifiable rocks and potential karst aquifers across the world

No.	State Party	World Heritage Property	Inscribed (extended)	Criteria	Key Karst Features	Environmental context
25*	Indonesia	Lorentz National Park	1999	viii, ix, x	Largest protected area in SE Asia (2.35M ha). Continuous transect from snow caps (5030 m) to tropical coast. World's best example of tropical alpine glaciated karst. Extensive humid tropical karst occurs at lower elevations. Huge sinking rivers and springs.	From the mountains to the sea. Tropical glaciated alpine to lowland tropical rainforest.
29*	Korea	Jeju Volcanic Island and Lava Tubes	2007	vii, viii	Oustanding example of vulcanokarst, a special style of pseudokarst. This includes Geomunoreum lava tubes which are notable for spectacular decoration with carbonate speleothems, the carbonate being derived from overlying calcareous dune sands blown in from the coast.	Warm temperate monsoonal.
30*	Madagascar	Tsingy de Bemaraha Strict Nature Reserve	1990	vii, x	Extensive areas of very sharp limestone pinnacle karst known locally as 'tsingy' with joint corridors up to 80 m deep occupied by forest. Traversed by river gorges. May be the world's most spectacular pinnacled terrain.	Tropical seasonally arid.
31*	Malaysia	Gunung Mulu	2000	vii, viii, ix, x	The park has a significant area of karst in Miocene limestone that contains large underground rivers and >290 km of explored caves, including Sarawak Chamber (700 m long, 300-400 m wide and up to 100m high) – the world's largest underground room. Caves contain major speleothem deposits and 1.5 million year sediment sequences. Rich cave biota, especially notable for bats and swiftlets. Surface features include giant collapse dolines and spectacular razor-sharp pinnacle karst (ca 50 m high).	Humid tropical rainforest with 17 vegetation zones covering altitude range to 2377 m.
34*	Palau	Rock Islands Southern Lagoon	2012	iii, v, vii, ix, x	A superb example of 445 partly drowned, well-karstified coral islands with flooded closed depressions as marine lakes.	Western Pacific oceanic tropical humid
35*	Philippines	Puerto-Princesa Subterranean River National Park	1999	vii, x	Spectacular tropical karst landscape in middle Miocene limestone on Palawan Island extending from mountains to the sea. Contains polygonal karst, towers and polje. Major underground river drains directly to the sea, lower portions of cave are tidal and navigable for 6 km.	Humid tropical rainforest environment. Most significant forest in Palawan Biogeographical Province.
37*	Russian Federation	Lena Pillars Nature Park	2012,	viii	Dolomitic limestone pillars along edges of Lena River and tributaries. Pillars were isolated by paleo-dissolution along joints beneath thick gravel cover and are revealed along valley sides by frost processes and fluvial undercutting. Karst features include groundwater circulation and small flutes.	World's most extreme continental climate with permafrost at base of soil extending to depth of several hundred metres.

No.	State Party	World Heritage Property	Inscribed (extended)	Criteria	Key Karst Features	Environmental context
38*	Russian Federation	Western Caucasus	1999	vii, x	A geologically complex region rising to over 3000 m. The northern section consists of alpine karst in Triassic limestones, much of it glaciated. Includes glaciokarst features, many deep gorges and deep caves. Incorporates complete karst systems.	Temperate to alpine continental climate. Largely undisturbed deciduous and coniferous forest and alpine meadows.
40*	Slovenia	Škocjan Caves	1986	vii, viii	Located in the 'classical' karst of Europe. The property comprises a sinking river at the end of blind valley, the exposed course of the underground river flowing across the base of deep collapse depressions, and a large river cave with a high canyon passage. It is representative of the input of an allogenic river into a karst system.	Continental Mediterranean climate.
42*	South Africa	Fossil Hominid Sites of South Africa	1999 (2005)	iii, vi	A cluster of karst sites in Proterozoic dolomite bedrock that contain remains of some of the earliest hominids as well as many other species. The caves contain internationally outstanding examples of cave sediments with fossils that were deposited over an interval of several million years into very ancient karst systems.	Subtropical High Veldt savannah environment.
45*	Turkey	Hierapolis-Pamukkale	1988	iii, iv, vii	Extensive and 200 m high valleyside travertine terrace with rimstone pools formed by carbonate deposition from geothermal water emerging at 59°C. Used as a spa since 2nd century B.C. Possibly the world's earliest karst tourist site still in use. Significant human impact.	Warm temperate Mediterranean environment.
46*	UK: Pitcairn Islands	Henderson Island	1988	vii, x	Raised coral atoll 30 km^2 in area with rough karstified 'makatea' plateau surface at about 30 m above sea level with central depression that may have been former lagoon. Island is bounded by 15 m high cliffs and fringing reef to 200 m wide. Limestone considered late Tertiary in age. An outstanding example of early phase of karstification with intact natural processes, but scientifically unevaluated. Some caves.	Tropical humid maritime climate supporting thick cover of trees and dense undergrowth. The only raised and forested atoll with its ecology intact.
48*	USA	Mammoth Cave National Park	1981	vii, viii, x	The longest cave in the world with 590 km of surveyed river passages, often large in dimension and gently sloping. The karst is developed in Lower Carboniferous (Mississippian) limestone and cave evolution commenced following uplift and exposure three to four million years ago. Extensive sinkhole plain at the surface. Large springs. Rich troglobitic fauna. The inflow margin of the karst is located beyond the Park boundary.	Humid warm temperate continental climate. Deciduous forest cover.

Annex 4: Distribution of karstifiable rocks and potential karst aquifers across the world

No.	State Party	World Heritage Property	Inscribed (extended)	Criteria	Key Karst Features	Environmental context
49*	USA	Carlsbad Caverns National Park	1995	vii, viii	Huge caverns extensively decorated with speleothems are a major feature of the park. The 81 known caves mainly occur in uplifted Permian reef limestones. Outstanding karst extends into neighbouring Guadalupe National Park. The region's caves provide the world's foremost example of evolution by sulphuric acid dissolution, which occurred progressively between 12 and four million years ago. Surface topography on back-reef dolomites and limestones is dominated by dry valleys. High biodiversity, including about 1 million bat population.	Subtropical semi-arid continental climate.
50*	Venezuela	Canaima National Park	1994	vii, viii, ix, x	The most outstanding example in the world of cave development in quartzite (Precambrian age). Caves occur to 10.8 km long and 383 m deep. Enclosed depressions and stream-sinks on plateau (tepuy) surface around 2650 m. Springs emerge in tepuy walls. A fluviokarst landscape.	Humid tropical upland rainforest environment.
51*	Viet Nam	Ha Long Bay	1994 (2000)	vii, viii	The world's most extensive and best-known example of tropical tower karst invaded by the sea. The Park area includes about 775 islands, some with caves. Incorporates areas of fengcong and fenglin karst. Significant human impact from surrounding development.	Humid tropical monsoonal environment.
52*	Viet Nam	Phong Nha-Ke Bang National Park	2003 (2015)	viii	Extensive and complex karst development in dissected plateau environment to 1290 m above sea level that continues across border into Laos. Long history of karst landscape evolution, possibly since early Mesozoic. Major caves and underground rivers and extensive enclosed depressions (polje).	Humid tropical monsoonal environment with largely undisturbed evergreen primary forest. Rich biodiversity.
53*	Viet Nam	Trang An Landscape Complex	2014	v, vii, viii	Tower karst in its end stages near sea level. Numerous navigable foot-caves, and extensive swamp notch and marine notch development reflecting sea level changes.	Humid tropical monsoonal environment in coastal context.

INTERNATIONAL UNION
FOR CONSERVATION OF NATURE

WORLD HEADQUARTERS
Rue Mauverney 28
1196 Gland, Switzerland
Tel +41 22 999 0000
Fax +41 22 999 0002
www.iucn.org