GEOLOGICAL WORLD HERITAGE: A GLOBAL FRAMEWORK

A Contribution to the Global Theme Study of World Heritage Natural Sites

Prepared by Paul Dingwall, Tony Weighell and Tim Badman

Protected Area Programme, IUCN

September 2005

IUCN The World Conservation Union

WCPA WORLD COMMISSION ON PROTECTED AREAS

PATRIMONIO MUNDIAL • WORLD HERITAGE • PATRIMOINE MONDIAL

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Front Cover: The Vredefort Dome, South Africa is the site of the world's oldest and largest known meteorite impact, and was inscribed on the World Heritage List in 2005 (Credit: Coenie Erasmus/erasmusc@dteea.fs.gov.za)

SUMMARY

This report discusses role of the *World Heritage Convention* in recognizing and protecting geological and geomorphological heritage, and presents proposals based on a global consultation.

The *World Heritage Convention* is capable of recognizing geological and geomorphological values either directly or indirectly. *Direct* recognition of such values comes through inscription of properties on the World Heritage List under criterion viii (formerly natural criterion i) either on its own or in combination with other natural or cultural criteria.

The *Convention* is also capable of recognizing the *supportive* value of geological and geomorphological values, underpinning biological, cultural and landscape diversity. The ways in which this might be achieved need further discussion.

The World Heritage process is highly selective with its underlying principles for the recognition of heritage of **outstanding universal value**, with a high level of site integrity/authenticity and effective site management. Some geological and geomorphological phenomena and sites, although of national or regional significance, will not be suitable for World Heritage inscription because they do not meet the criteria of **outstanding universal value** or satisfy the required conditions of integrity or management.

In determining the potential role of the *World Heritage Convention* in protecting/recognizing a particular property, States Parties, regional experts and international organizations should:

- fully consider the use of alternative designation options, through national or international programmes;
- consider if a property merits nomination under criterion viii (alone or in combination with other criteria) or if the geological and geomorphological values are better represented as supporting biodiversity, cultural or landscape values.
- undertake a rigorous global comparative analysis to ensure that a property does have global significance.

A thematic approach is presented in this report, with thirteen geological and geomorphological themes proposed as the basis for assessing properties for World Heritage potential. These themes are proposed in support of the application of criterion viii and are designed 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..

A thematic approach will also assist international bodies and regional experts to systematically identify geological and geomorphological sites of potential World Heritage status. It is not possible to attempt this analysis at present and this report does not attempt to do so.

The UNESCO Geoparks program offers scope for the recognition of internationally significant sites and is becoming increasingly used in Europe, South-east Asia and South America to recognize landscapes with significant geological and geomorphological values. The Geoparks initiative offers a significant alternative to World Heritage inscription.

A series of recommendations are made to assist the international earth heritage community better understand the scope and purpose of the *World Heritage Convention*, and its limitations. It is strongly recommended that the geological and geomorphological themes are widely disseminated within the earth heritage community, and that strong partnerships are developed between partners in World Heritage, including IUCN and the leading international earth science unions, to develop and implement the conclusions of this report.

RÉSUMÉ

Ce dossier développe plus amplement des propositions émises et revues depuis octobre 2002. Il inclut des discussions sur des questions supplémentaires concernant le rôle de la *Convention du Patrimoine Mondial* dans le cadre de la reconnaissance et de la protection du patrimoine géologique et géomorphologique.

La *Convention du Patrimoine Mondial* permet de reconnaître des valeurs géologiques et géomorphologiques, soit d'une manière directe ou indirecte. La reconnaissance directe de telles valeurs apparaît à travers l'inscription de biens sur la Liste du Patrimoine mondial sous le critère viii (anciennement appelé critère naturel i), de manière individuelle ou en combinaison avec d'autres critères naturels ou culturels.

La *Convention* permet également de reconnaître la valeur 'supportive' de valeurs géologiques et géomorphologiques, en ce qui concerne les diversités biologiques et culturelles, ainsi que celles des paysages. La mise en place de ces propriétés nécessite de plus amples discussions.

Le processus du Patrimoine Mondial est extrêmement sélectif en ce qui concerne ses principes fondamentaux de reconnaissance du patrimoine d'une valeur universelle exceptionelle, des biens avec un haut niveau d'intégrité/ authenticité, et de gestion efficace.

Bien que certains phénomènes et biens géologiques et géomorphologiques ont une signification régionale ou nationale, ils ne seront pas appropriés pour être inscrit au Patrimoine Mondial parce qu'ils n'ont pas de valeur universelle exceptionelle et ne satisfont pas les conditions d'intégrité ou de gestion.

Afin de déterminer le rôle potentiel de la *Convention du Patrimoine Mondial* dans la classification d'un site naturel particulier, les États parties, les experts régionaux et les organisations internationales devraient :

- considérer entièrement l'utilisation d'options alternatives de désignation, à travers des programmes nationaux ou internationaux ;
- évaluer si un bien mérite d'être classé sous le critère viii (individuellement ou en combinaison avec d'autres critères) ou si les valeurs géologiques et géomorphologiques seraient mieux représentées en contribuant aux valeurs de la biodiversité, de la culture ou du paysage.
- entreprendre une analyse comparative rigoureuse et globale afin de s'assurer que le bien proposé possède une signification globale.

Une approche thématique est présentée dans le dossier, sous la forme de trente thèmes géologiques et géomorphologiques proposés en tant que bases d'évaluation des biens proposé au patrimoine mondial. Ces thèmes sont proposés en complément de l'application du critère viii et sont désignés afin de:

- assister les États parties pour qu'elles entreprennent une analyse comparative globale des biens antérieures et inhérents aux nouvelles propositions sous le critère viii ;
- aider le Comité du Patrimoine Mondial et ses conseillers, afin qu'ils identifient d'éventuelles lacunes dans la Liste du Patrimoine Mondial ;
- aider le Comité du Patrimoine Mondial et ses conseillers dans leurs évaluations des nouvelles propositions des biens sous le critère viii.

Une approche thématique va également aider les organisations internationales et les experts régionaux à identifier systématiquement les biens géologiques et géomorphologiques à potentiel de Statut du Patrimoine Mondial. En ce moment, il n'est pas possible d'entreprendre cette analyse et ce dossier ne cherche pas à le faire.

Le programme Geoparks de l'UNESCO offre la possibilité de reconnaître des sites de signification internationale et est de plus en plus usité en Europe, en Asie du Sud-est, et en Amérique du Sud afin de reconnaitre des paysages aux valeurs géologiques et géomorphologiques. L'initiative Geoparks propose une alternative considerable à la désignation du Patrimoine Mondial.

Une série de recommandations ont été réalisées pour aider la communauté internationale du patrimoine géologique à mieux comprendre l'envergure et l'utilité de la *Convention du Patrimoine Mondial*, ainsi que ses restrictions. Il est fortement recommandé que les thèmes géologiques et géomorphologiques soient largement disséminés à travers la communauté du patrimoine géologique et que d'étroites relations soient entretenues entre des partenaires du Patrimoine Mondial, y compris l'UICN, et les unions internationales les plus importantes de la science de la Terre afin de développer et mettre en œuvre les conclusions du dossier.

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1. SCOPE AND PURPOSE

This report provides a review of World Heritage properties[1] that are inscribed on geological/ geomorphological criteria and other properties that have geological interest. The report does not attempt to identify potential areas of geological interest for new nominations. This would be premature given the current level of understanding in the geological community as to the scope and purpose of the *World Heritage Convention*. The report contains recommendations as to how such potential World Heritage properties could be identified in the short/medium term.

It is important that States Parties[2] to the *World Heritage Convention*, and those involved in geological conservation recognize that other conservation measures may be more appropriate for important geological sites than World Heritage status. It is also important that the nature of the World Heritage nomination process becomes better understood by those involved in geological conservation. This review is designed to work towards this end.

In summary, this report reviews:

- **Operation of the *World Heritage Convention*** in respect of natural heritage in general and with particular regard to geological/geomorphological conservation;
- **The World Heritage nomination process** with emphasis on the role of Tentative Lists prepared by States Parties, and of rigorous comparative analysis in identifying geological properties of potential World Heritage status;
- **Possible geological and geomorphological themes** that can be adopted to inform site selection and evaluation processes;
- **Mechanisms and opportunities for recognizing geological heritage** other than the *World Heritage Convention* that may support the objectives of the *Convention*.

A series of recommendations are made to assist the international earth science community to better understand the role of the *World Heritage Convention* and to offer guidance that encourages States Parties to nominate new sites within a thematic framework.

This document is intended as a contribution to an ongoing debate and will be revised from time to time as necessary.

[1] 'Property' is the term generally used by UNESCO to describe a site inscribed on the World Heritage List.
[2] States that are party to the *World Heritage Convention*, i.e are signatories to the *Convention.*

2. THE WORLD HERITAGE CONVENTION

2.1 Overview

The *World Heritage Convention* is rooted in the recognition that the most priceless and irreplaceable assets of cultural and natural heritage need protection, not only for each nation, but for humanity as a whole. The loss of these most prized assets, either through deterioration or disappearance, constitutes an impoverishment of the heritage of all the peoples of the world. Parts of that 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.

To ensure, as far as possible, the proper identification, protection, conservation and presentation of the world's heritage, the Member States of UNESCO adopted the *World Heritage Convention* in 1972. The *Convention* foresees the establishment of a "World Heritage Committee" and a "World Heritage Fund". Both the Committee and the Fund have been in operation since 1976. The *Convention* aims at the identification, protection, conservation, presentation and transmission to future generations of cultural and natural heritage of **outstanding universal value**.

Criteria and conditions for the inscription of properties on the World Heritage List have been developed to evaluate the **outstanding universal value** of properties and to guide States Parties in the protection and management of World Heritage properties. When an inscribed property on the World Heritage List is threatened by serious and specific dangers, the Committee considers placing it on the List of World Heritage in Danger. When the **outstanding universal value** of the property which justified its inscription on the World Heritage List is destroyed, the Committee considers deleting the property from the World Heritage List.

The main guidance on the *World Heritage Convention* is set out in *the Operational Guidelines to the World Heritage Convention*. The *Operational Guidelines* provide the best source of official advice on the overall operation of the *Convention*. Copies of the *Convention* and *Operational Guidelines* may be obtained from UNESCO, including via the World Heritage website (whc.unesco.org). The *Operational Guidelines* are reviewed and updated periodically, and this report refers to the version updated in February 2005.

2.2 Outstanding Universal Value

A crucial principle guiding the World Heritage Committee is that the *Convention* provides for the protection of cultural and natural properties deemed to be of **outstanding universal value.**

Paragraph 49 of the *Operational Guidelines* defines this concept as follows:

> *49. **Outstanding universal value** means cultural and/or natural significance which is so exceptional as to transcend national boundaries and to be of common importance for present and future generations of all humanity. As such, the permanent protection of this heritage is of the highest importance to the international community as a whole. The Committee defines the criteria for the inscription of properties on the World Heritage List.*

The selective nature of the World Heritage List is further emphasized in paragraph 52:

> *52. The 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. It is not to be assumed that a property of national and/or regional importance will automatically be inscribed on the World Heritage List.*

The *Operational Guidelines* set out the key tests that the World Heritage Committee applies to decide whether a property is of **outstanding universal value** in paragraphs 77 and 78 of the *Operational Guidelines*:

> *77. The Committee considers a property as having **outstanding universal value** ... if the property meets one or more of the [World Heritage] criteria.*
>
> *78. To be deemed of **outstanding universal value**, a property must also meet the conditions of integrity and/or authenticity and must have an adequate protection and management system to ensure its safeguarding.*

Integrity and authenticity are also given particular meaning within the *Operational Guidelines*. Authenticity is primarily an attribute in relation to cultural properties, whilst integrity is a requirement of both cultural and natural properties. Integrity is defined thus in paragraph 88 of the *Operational Guidelines*:

> *88. Integrity is a measure of the wholeness and intactness of the natural and/or cultural heritage and its attributes. Examining the conditions of integrity, therefore requires assessing the extent to which the property:*
>
> *a) includes all elements necessary to express its **outstanding universal value**;*
> *b) is of adequate size to ensure the complete representation of the features and processes which convey the property's significance;*
> *c) suffers from adverse effects of development and/or neglect.*

2.3 Natural Heritage in the *World Heritage Convention*

Article 2 of the *World Heritage Convention* defines *'natural heritage'* as follows:

- *natural features consisting of physical and biological formations or groups of such formations, which are of **outstanding universal value** from the aesthetic or scientific point of view;*
- *geological and physiographical formations and precisely delineated areas which constitute the habitat of threatened species of animals and plants of **outstanding universal value** from the point of view of science or conservation;*
- *natural sites or precisely delineated natural areas of **outstanding universal value** from the point of view of science, conservation or natural beauty' .*

As noted above, to merit inclusion on the World Heritage List, properties will be regarded as of **outstanding universal value** if they meet one of the World Heritage criteria. Ten such criteria are set out in the *Operational Guidelines* (paragraph 77). The first six of these relate to cultural values, whilst the remaining four define the criteria for natural World Heritage. Until 2005, these criteria were set out in two separate groups: six cultural criteria and four natural criteria. The four natural criteria now form part of a single list, and are numbered and defined in the *Operational Guidelines* as follows:

- *Criterion vii (previously Natural criterion iii): 'contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance; or*
- *Criterion viii (previously Natural criterion i) 'be outstanding examples representing major stages of earth's history, including the record of life, significant on-going geological processes in the development of land forms, or significant geomorphic or physiographic features; or*
- *Criterion ix (previously Natural criterion ii) 'be outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, freshwater, coastal and marine ecosystems and communities of plants and animals; or*
- *Criterion x (previously Natural criterion iv) '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 conservation.*

The *Convention* also makes provision for the inscription of cultural landscapes, which are the *'combined works of man and nature'*. For more information on the full range of criteria, cultural landscapes and the interaction on natural and cultural aspects please refer initially to the *Operational Guidelines*.

2.4 The World Heritage Nomination Process

The nomination of natural properties for World Heritage status follows a set procedure set out in the *Operational Guidelines*, which can be summarized as follows:

- **Step 1:** States Parties identify and evaluate suitable properties within their boundaries and prepare a Tentative List.
- **Step 2:** States Parties prepare nomination documents for each property, these to include an evaluation of the **outstanding universal value** (in natural or cultural heritage terms) of the property and a management plan.
- **Step 3:** Properties nominated on the basis of natural values are assessed by the IUCN who make a written report to the World Heritage Committee.
- **Step 4:** The World Heritage Committee considers each nomination and successful nominations result in a property being inscribed on the World Heritage List.

Opportunities exist throughout the nomination process for a State Party to seek advice from regional or international expert groups, the World Heritage Centre and the IUCN.

2.5 Role of Tentative Lists

A Tentative List is an inventory of those properties situated on its territory which each State Party considers suitable for inscription on the World Heritage List. States Parties should therefore include, in their Tentative Lists, the names of those properties which they consider to be cultural and/or natural heritage of **outstanding universal value** and which they intend to nominate during the following years.

Nominations to the World Heritage List are not considered unless the nominated property has already been included on the State Party's Tentative List.

States Parties are encouraged to prepare their Tentative Lists with the participation of a wide variety of stakeholders, including site managers, local and regional governments, local communities, NGOs and other interested parties and partners.

States Parties shall submit Tentative Lists to the Secretariat, preferably at least one year prior to the submission of any nomination. States Parties are encouraged to re-examine and re-submit their Tentative List at least every ten years.

Inclusion of a site on a Tentative List implies that sufficient analysis has already been undertaken to indicate that the site has potential to be recognized as of **outstanding universal value**, although this may not happen in practice. For successful nomination, sites will also need to satisfy conditions of integrity and management. It is a requirement that properties should be placed on the Tentative List of the State Party prior to nomination.

2.6 The Importance of Comparative Analysis

Demonstration of **outstanding universal value** within a World Heritage nomination requires comparative analysis with other sites at the global - not national or regional - level. This comparison should be based on an analysis of existing World Heritage properties and reference to existing comparative studies. Advice should also be sought from the IUCN and the World Heritage Centre. Further advice may also be sought from international earth science bodies in relation to geological and geomorphological sites.

Appropriate comparative analysis of site geological/geomorphological values is of the highest importance to ensure that a good case is made for **outstanding universal value**, and to ensure that other protected area options are considered. It should be noted that the World Heritage Committee has made particularly strong calls for nominations of geological properties to be accompanied by a thorough, global comparative analysis.

There are two basic requirements concerning the importance of Comparative Analysis for nominated properties: (1) The Comparative Analysis needs to be global in scope. The nominated property should be compared with other similar properties that exist around the world based, where possible, on a global classification system, and; (2) The nominated property should be compared not only with properties already inscribed on the World Heritage List but also with other similar properties worldwide. These two basic requirements serve to explain the importance of the nominated property in an international context, hence ensuring that a good case is made of outstanding universal value.

While a Global Comparative Analysis is an integral part of the nomination dossier it should be seen as an important step to be undertaken by the State Party before the property is nominated. States Parties should be encouraged to carry out a brief Comparative Analysis during the process of compiling properties onto the Tentative List. Rigorous comparative analysis prior to inclusion of a site on a Tentative List on the basis of criterion viii is an important first step in assessing the World Heritage potential of a property. Even if a property does not have **outstanding universal value** for geological and geomorphological features, these may be significant in underpinning biological, cultural or landscape values and deserve recognition for this. A key source of information for comparative analyses lies within the 'case law' of the *Convention,* in the form of the decisions of the World Heritage Committee and the record of advice from the advisory bodies. This information is also readily available on the UNESCO World Heritage website (whc.unesco.org). More information on comparative analysis in relation to natural properties is included within Appendix 3, together with some examples from relevant geological sites.

3. RECOGNITION OF GEOLOGY AND GEOMORPHOLOGY ON THE WORLD HERITAGE LIST

3.1 Criterion viii: the Geological Criterion of the *World Heritage Convention*

The *Operational Guidelines* describe the ability of the *World Heritage Convention* to recognize geological phenomena, through the list of World Heritage criteria, and criterion viii provides the primary mechanism for such recognition. To merit inscription on the World Heritage List, a geological or geomorphological site must meet this criterion. Criterion viii recognizes four different natural elements relevant to geological and geomorphological science. These are underlined as follows:

- ***Criterion viii: '[to be of outstanding universal value, properties should] be outstanding examples representing major stages of earth's history, including the record of life, significant on-going geological processes in the development of land forms, or significant geomorphic or physiographic features;'***

These four elements can be summarized as follows, and more guidance on the way in which their values are identified within the *World Heritage Convention* is provided in Appendix 3.

a. Earth's history

This subset of geological (as opposed to geomorphological) features are represented by phenomena that record important events in the past development of the planet such as:

- the record of crustal dynamics and tectonism, linking the genesis and development of mountains, volcanoes, plate movements, continental movement and rift valley development;
- records of meteorite impacts;
- records of glaciations in the geological past.

Sites in this category would be of **outstanding universal value** in exhibiting elements of earth history through rock sequences or associations rather than fossil assemblages.

b. The record of life

This subset includes paleontological (fossil) sites. The role of such sites in the World Heritage List, and the basis for selecting/evaluating such sites has been reviewed in detail in an IUCN Thematic Study (Wells, 1996). A range of the properties have been inscribed on the World Heritage List, having been assessed as being of **outstanding universal value**. Wells presents the diagram right (Figure 1) to illustrate the nature of life on the planet through time, and the record that the *World Heritage Convention* can attempt to capture. Figure 2 (overleaf) shows how the current fossil sites on the World Heritage List (at July 2005) are distributed in relation to geological time. More information is available from the thematic study directly, and it is essential reading in relation to nominations of properties with fossil values.

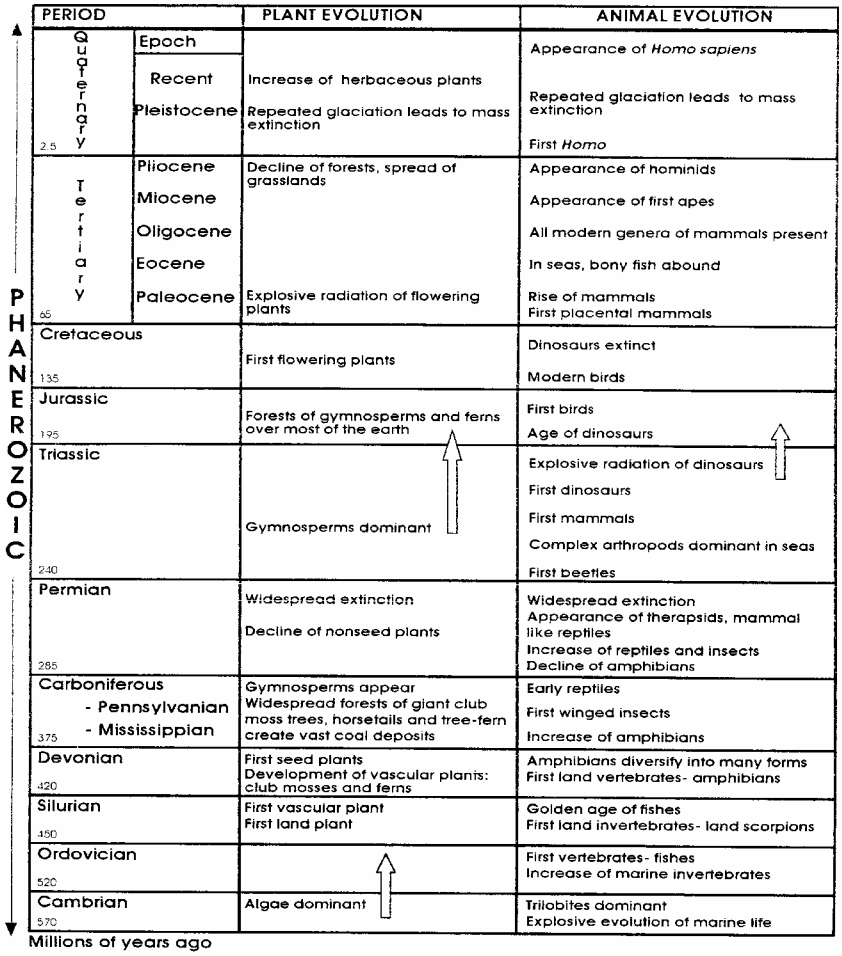

Figure 1 – Nature of life on Earth through time – from Wells (1996)

Geological Period	Key Biological Event	World Heritage Site
Quaternary	Humans appear Ice Age	Naracoorte (Australia)
Pliocene		
Miocene		Riversleigh (Australia)
Oligocene		
Eocene		Messel Pit (Germany) Wadi Al-Hitan (Egypt)
Paleocene	First primates	
Cretaceous	Extinction of dinosaurs Origin of flowering plants	Dinosaur Park (Canada) 75m years
Jurassic	Age of dinosaurs First birds	Dorset/East Devon (U.K)
Triassic	First mammals/dinosaurs	Dorset/East Devon (U.K.) Ischigualasto-Talampaya (Argentina) Monte San Giorgio, (Switzerland)
Permian		Grand Canyon (USA)
Carboniferous	First reptiles	Mammoth Cave (USA)
Devonian	First amphibians/forests	Miguasha (Canada)
Silurian	First land plants	
Ordovician	First fishes/corals	Gros Morne (Canada)
Cambrian	First trilobites	Burgess Shale (Canada)
Precambrian	First algae/bacteria	

Figure 2: The representation of geological time periods by fossil sites within the World Heritage List (at 2005) (adapted from Wells, 1996).

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c. Significant on-going geological processes in the development of landforms

This element of criterion viii is the first of two aspects related to geomorphology, and ongoing geological processes such as volcanic eruptions. It relates to **active processes** that are shaping or have shaped the Earth's surface. Properties recognized within this part of criterion viii include those that are of **outstanding universal value** as examples of:

- Arid & Semi Arid desert processes;
- Glaciation;
- Volcanism;
- Mass movement (terrestrial and submarine);
- Fluvial (river) and deltaic process processes;
- Coastal and marine processes.

d. Significant geomorphic or physiographic features.

This second primarily geomorphological element represents the landscape **products** of active or past processes, which can be identified as significant physical landscape features. Criterion viii recognizes these features in relation to their scientific value, however they frequently may also be of aesthetic value. Properties recognized within this part of the criterion may include those of **outstanding universal value** as:

- Desert landforms
- Glaciers and ice caps
- Volcanoes and volcanic systems, including those that are extinct
- Mountains
- Fluvial landforms and river valleys
- Coasts and coastal features
- Reefs, atolls and oceanic islands
- Glacial and periglacial landforms, including relict landscapes
- Caves and Karst.

3.2 Direct and Indirect Recognition of Geological and Geomorphological Sites on the World Heritage List.

Criterion viii makes direct provision for the recognition and protection of geological and geomorphological properties under the *World Heritage Convention*. Sites with geological/ geomorphological interest may be inscribed on the World Heritage List on the basis of criterion viii alone or in combination with other criteria. As of July 2005, c.71 properties have been inscribed for their earth science values defined in criterion viii and therefore can be taken to directly recognize geological and geomorphological values[3].

Geological and geomorphological values may also be important for World Heritage properties that are inscribed, or are to be nominated on criteria other than criterion viii. The World Heritage status of such sites can be used to recognize these geological values without direct inscription through criterion viii. Geological/geomorphological values may underpin biodiversity and cultural diversity and this can be recognized through site description documents and site management plans.

Explicit recognition of the full range of natural values of a World Heritage property, by reference to such geological and geomorphological values in site documentation and management plans, will allow these values to be understood and protected within the property (as 'supporting values') even when they are not the main reason for inscription on the World Heritage List. The geology and geomorphology of such sites may have national or regional significance but may not be of **outstanding universal value**. In the case of such geological/ geomorphological values, these should be recognized wherever possible and appropriate as part of the natural values underpinning the **outstanding universal value** of a property.

Figure 3 illustrates how geological and geomorphological values can be recognized directly or indirectly by the World Heritage process.

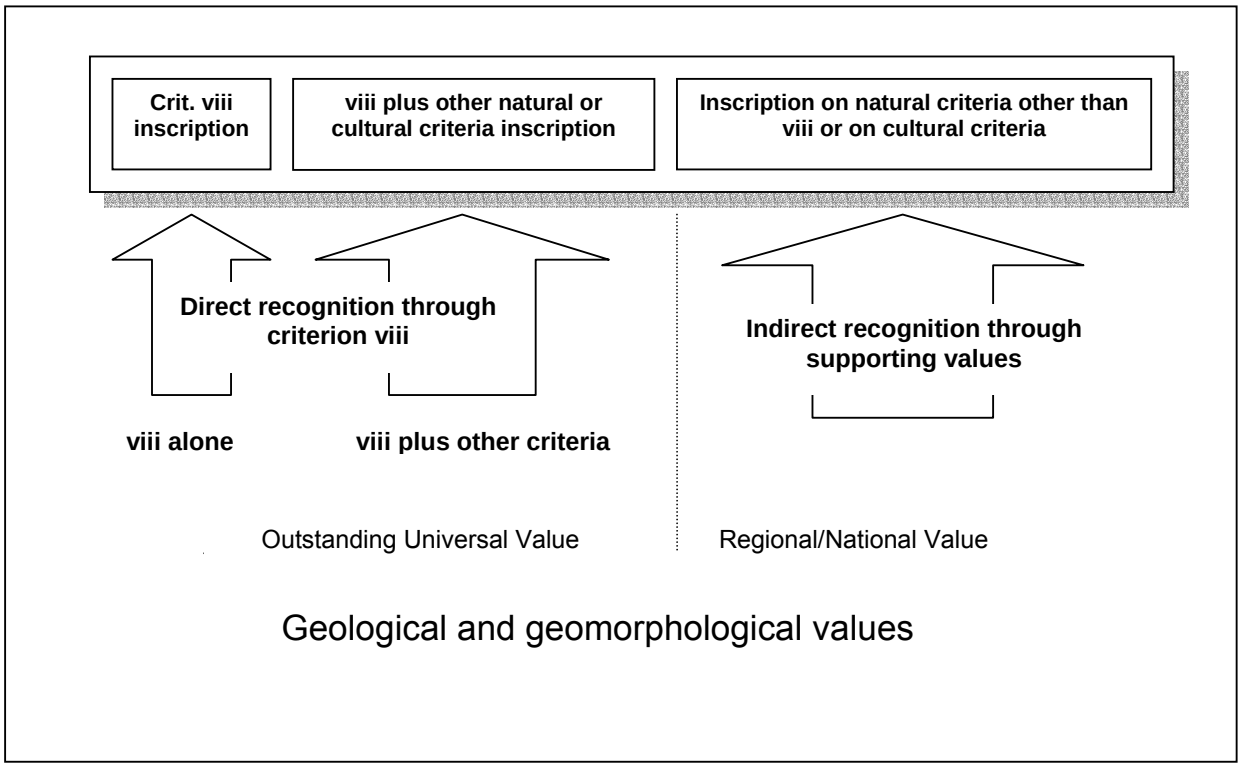

Figure 3: Direct and indirect recognition of geology and geomorphology through the World Heritage Convention

[3] This figure takes account of the changes in wording that have taken place within the World Heritage criteria over the history of the Convention, and is approximated as some judgements were made under criteria with slightly different wording or organisation. For more information please see Appendix 1. At July 2005 there were 812 properties on the World Heritage List, of which 160 were natural and 24 mixed (inscribed for cultural and natural features).

4. A THEMATIC APPROACH TO GEOLOGICAL WORLD HERITAGE

As described above, the *Operational Guidelines* to the *Convention* make clear, through criterion viii, the type of geological/geomorphological phenomena that the *Convention* wishes to recognize as being of **outstanding universal value**. The four subsets of interest within criterion viii provide general guidance on the aspects that the Convention seeks to recognize, but it is helpful to develop these into a set of consolidated themes.

The diversity of geological and geomorphological phenomena that can be accommodated on the World Heritage List is considerable and the use of a thematic strategy that sets up a basic classification scheme will enable logical decisions to be made in preparing nominations and within site evaluation. Any thematic classification must reflect the fact that the *World Heritage Convention* can only recognize a limited number of sites. The classification scheme used to assist in site selection and evaluation should therefore not be over-elaborate.

Based on the analysis of criterion viii set out in Chapter 2, thirteen major thematic areas are recommended as a broad conceptual framework for geological World Heritage. They provide a basis within which nominated World Heritage natural properties can be examined in order to assess their claim to **outstanding universal value** from the viewpoint of science and conservation. It is hoped that they will assist national and regional experts to assess the relative importance of sites, and for the IUCN to assess nominations and offer advice to interested parties.

The thirteen themes are proposed as follows:

1. Tectonic and structural features
Elements of global-scale crustal dynamics including continental drift and seafloor spreading. Major crustal landforms and structural features at plate boundaries. Geosyncline/anticline development and erosion; rift-valley systems.

2. Volcanoes/volcanic systems
Major areas and types of volcanic origin and evolution. These may include examples of major features such as the “Pacific Ring of Fire” as a global-scale expression of volcanic activity and associated crustal movements.

3. Mountain systems
Major mountain zones and chains of the world.

4. Stratigraphic sites
Rock sequences that provide a record of key earth history events.

5. Fossil sites
The record of life on Earth represented within the fossil record (see also Wells, 1996).

6. Fluvial, lacustrine and deltaic systems
Land systems resulting from large-scale river erosion and drainage system development, lakes, wetlands and deltas.

7. Caves and karst systems
Subterranean hydrological processes and landforms, together with their surface expressions

8. Coastal systems
The role of water at oceanic margins on large-scale erosional and depositional coasts and banks.

9. Reefs, atolls and oceanic islands
Geo-biological and/or volcanic features in oceanic areas or with oceanic influences.

10. Glaciers and ice caps
The significant role of ice in landform development in alpine and polar regions, including periglacial and nivation (snow) influences.

11. Ice Ages
Global patterns of continental icesheet expansion and recession, isostasy, sea-level changes, and associated biogeographic records.

12. Arid and semi-arid desert systems
Land systems and features reflecting the dominant role of wind (eolian processes) and intermittent fluvial action as agents of landform development and landscape evolution.

13. Meteorite impact
Physical evidence of meteorite impacts (astroblemes), and major changes that have resulted from them, such as extinctions.

The adoption of a thematic approach does not imply equal representation on the World Heritage List of each theme. Nor does it automatically imply that sites of suitable quality will be found for each theme. Sites will be required to satisfy not only the conditions of **outstanding universal value**, but also the requirements of integrity and management. Some themes may only be represented by very few sites, because even the best sites within a theme may not satisfy integrity/management criteria. The thematic approach is, however, seen as vital to the support of criterion viii and is designed to:

- assist State Parties to undertake global comparative analysis 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 sites.

A provisional analysis of the natural and mixed properties on the World Heritage List in relation to the thirteen themes is provided in Appendix 1.

5. RECOGNITION OF GEOLOGICAL AND GEOMORPHOLOGICAL HERITAGE OUTSIDE THE *WORLD HERITAGE CONVENTION*

National and international programs for recognizing sites of geological or geomorphological interest are less well developed than for biological conservation, particularly at the international level. Appendix 2 to this report provides details of the programs summarized here.

5.1 National Programs

National systems have the potential to recognize many sites of different characters and sizes that represent the earth heritage resources of that country. Many countries have national geoconservation programs and these cover a wide range of approaches to inventory and documentation of the diversity of geological and geomorphological phenomena (see Appendix 2 for definitions). Dixon (1996) provides a summary of many of these national schemes, while European approaches are broadly canvassed by papers from the Third International ProGEO Symposium (Barrettino et al. 1999).

Such reviews of experience from around the world reveal two basic approaches to geodiversity or geosite inventory, referred to by Dixon (1996). First order inventories are those that are based primarily on existing information and are largely unsystematic in approach: the majority of natural schemes appear to fall into this category. Second order inventories are more systematic and objective since they rely on a classification system. Some examples of the systematic approaches are outlined in the Appendix 2. Some countries provide for the protection of geological sites through national park or equivalent legislation and/or policy: this can potentially provide a high level of protection depending on the country and the legislation.

5.2 UNESCO Geoparks Program

The UNESCO Geoparks Program (Weighell, 1999) is philosophically founded in the 1991 Digne *"Declaration of the Rights of Memory of the Earth",* Geoparks aim to be a global series of geological sites intended to integrate the preservation of geological heritage and sustainable resource and economic development. In this respect Geoparks are considered to be in harmony with the objectives of Biosphere Reserves under the UNESCO Man and the Biosphere Program (MAB). They are also regarded as complementary to the World Heritage List, in providing an appropriate mechanism for recognizing internationally important sites identified from both national and international geological inventories.
Geoparks guidelines reveal the multiple roles and purposes for Geopark establishment and management (Anon. 2000a).

Six principles are specified for recognizing Geoparks, relating to their size, composition, socio-economic objectives, conservation objectives, education and research objectives, and to legal status and sovereignty issues. A further six criteria are provided for site nomination relating to composition (number of geosites), promotion of socio-economic development, conservation of geodiversity, education and research role, management planning, and management authority and co-operation.

The Geoparks program incorporates a highly innovative policy mandate in giving recognition to the interests of social advancement and economic resource development. Clearly, however, the role and purpose of geosite protection fulfilled by Geoparks designation are different from those of the *World Heritage Convention*. The rationale underscoring the relationship between Geoparks and World Heritage sites is that the World Heritage List is never likely to include more than 150 sites of primary geological or geomorphological interest. The necessarily selective nature of World Heritage listing cannot, therefore, be regarded as adequate for recognizing the full range of globally significant geological sites.

The Geoparks program remains a UNESCO initiative rather than an officially adopted program, but is rapidly developing in several regions of the world. A significant European Geoparks network has now been established with sites recognized across western Europe. Malaysia and China are developing the concept in South-east Asia, and the Chinese are establishing a global centre to coordinate development of a global network of sites in collaboration with UNESCO. Argentina is also working towards recognizing sites under this label.

The International Union of Geological Sciences (IUGS), in collaboration with UNESCO and the International Geographical Union (IGU), have recently decided to adopt a 'Geoparks Approach' to promoting the earth sciences, as a key part of a geoconservation program under the title GEOSEE. This concept is in development but recognizes that the principles that underlie Geoparks as 'protected' areas (the social, economic and scientific dimensions to the earth sciences) can be usefully employed within and beyond protected areas to promote the importance of the earth sciences to society in general. The UNESCO - IGU -

IUGS collaboration on this project should strengthen and broaden the appeal of the Geoparks program in its widest sense.

5.3 Summary of options for recognizing and protecting geological heritage

It is useful to compare the options for recognition and protection of geological/geomorphological sites to those available for biological sites. Biological conservation values at the international level can be recognized via range of designations: World Heritage, Ramsar, Man & Biosphere Reserves (MAB). These can be complementary and deployed according to circumstance. The MAB program is a particularly important compliment to the World Heritage List in that it recognizes representative sites. A similar official UNESCO designation does not yet exist for geological sites although the 'Geoparks' concept has been developed to fit this role. UNESCO currently supports the use of the concept to recognize representative sites (see Appendix 2).

Based on existing programs there are three routes to recognition/protection of geological sites:

- **national** designation, on a stand-alone geological basis or as part of a protected area program that includes biological, cultural and geological conservation;
- as a **'Geopark'** using the UNESCO model;
- recognition as a **World Heritage** site.

This hierarchy offers less opportunity for geological and geomorphological conservation than available for the biological equivalent. As a consequence, with only the *World Heritage Convention* providing a high level of international recognition for geological and geomorphological properties, there may be a tendency for inappropriate sites to be nominated. Guidance as to the scope and purpose of the *Convention* in recognizing geological and geomorphological properties, and the best use of the alternatives, is therefore needed for the geoconservation community. It should be recognized that the Geoparks program is expanding and developing globally, and now offers a significant complementary program to World Heritage listing. This alternative should be recognized and promoted.

6. CONCLUSIONS ON THE USE OF THE *WORLD HERITAGE CONVENTION* FOR RECOGNITION AND PROTECTION OF GEOLOGICAL AND GEOMORPHOLOGICAL HERITAGE

The following conclusions are offered on the basis of this review.

- The *World Heritage Convention* is highly selective in its recognition of cultural and natural heritage. For natural heritage, the *Convention* rigorously applies the concept of **outstanding universal value**. The *Convention* does not seek to recognize representative sites, simply the best global sites.

- Direct recognition of geological and geomorphological heritage through the *Convention* and through the use of criterion viii will ultimately recognize only a relatively small number of global sites.

- There is a 'secondary' role for the *Convention* in recognizing the supporting value of geology and geomorphology within World Heritage properties inscribed for biological or cultural values. Geological and geomorphological values are also important within the context of 'Cultural Landscapes'. These two secondary roles for the *Convention* are currently not fully developed and require further guidance.

- There is a need to raise the level of awareness and understanding of the opportunities that the *Convention* offers within the geoconservation community to recognize earth science values, both directly and indirectly, whilst stressing the limitations imposed by the concept of **outstanding universal value**. It would be of benefit, to both the operation of the *Convention* and to the global geoconservation community, to promote a greater understanding of how the *Convention* can best recognize geological and geomorphological heritage. Opportunities exist for collaboration with international organizations, including the International Union of Geological Sciences, International Geographical Union and their related Associations, to identify more fully what can be achieved through the *Convention* in respect of geoconservation, as well as its limitations.

- It is not possible at this stage, or through this report, to systematically identify possible new sites for nomination under criterion viii. Thirteen geological/geomorphological themes are proposed that support criterion viii and could form the basis for future identification of new sites for inscription under this criteria. The thematic approach also supports State Parties in their attempts to conduct the necessary comparative analysis of sites prior to nomination.

- Each proposed theme needs further detailed work utilizing international expert opinion. This detailed analysis could shape possible regional sub-themes that might assist States Parties in preparing their Tentative Lists, formulating future nominations and in identifying where transnational cooperation might be of benefit.

- There is a need for a set of published guidelines that make clear the World Heritage nomination process as it applies to geological/ geomorphological sites, and the scope and limitations of the *Convention* in this respect. The proposed content of such guidance is suggested in the Recommendations section of this report.

- The *Convention* needs to be understood as a highly selective way in which to recognize important geological/geomorphological sites, but should also be promoted as a model for recognizing this form of natural heritage, in terms of its scientific importance but also it's social, economic and landscape aspects.

7. RECOMMENDATIONS

Recommendation 1: Promote guidance (for use by States Parties, the World Heritage Centre, Advisory Bodies and other bodies interested in earth science conservation) on the World Heritage nomination process as it should be applied to geological/geomorphological sites. This guidance to include:

- emphasis on the concept of **outstanding universal value**;
- a set of geological/geomorphological themes;
- emphasis on the need for comparative analysis before placing sites on national Tentative Lists and guidance on undertaking such analysis;
- emphasis on the need to consider alternative means of recognizing/protecting sites prior to undertaking a World Heritage nomination;
- emphasis on the need to consult the IUCN and World Heritage Centre early in the nomination process.

Such guidance should be published in the earth science literature and on the UNESCO World Heritage website.

Recommendation 2: This report identifies thirteen themes that can be used to evaluate World Heritage nominations and assist State Parties identify sites for nomination on the basis of criterion viii . Further work needs to be done to provide more detailed information on these themes to allow them to be used effectively.

Recommendation 3: Review current States Parties Tentative Lists to identify geological/ geomorphological (criterion viii) nominations with the intention of offering early advice to State Parties as per the proposed guidelines above.

Recommendation 4: The IUCN, as advisors to the World Heritage Committee, should establish a formal relationship with the International Union of Geological Sciences (IUGS), the International Geographical Union (IGU) and relevant associations, such as the International Association of Geomorphologists, to provide access to a wider pool of expertise that can be used to ensure adequate assessment of World Heritage nominations that involve geology/geomorphology.

Recommendation 5: The Geoparks Program, which has been pioneered by UNESCO, is now (2005) being promoted in conjunction with the IUGS and IGU through the GEOSEE initiative. This approach (which is now well developed in China, Malaysia and Europe, and is being developed in Argentina) should be seen as a viable complement to World Heritage listing, and should be jointly promoted as such by the IUCN and the IUGS. This would provide one mechanism to avoid inappropriate sites being nominated for WH status.

Recommendation 6: The World Heritage Committee, the World Heritage Centre and the IUCN should encourage bilateral assistance between State Parties to share experience and build capacity. State Parties with recent experience of successful nomination of geological/ geomorphological sites should be encouraged to assist those preparing such nominations.

Recommendation 7: The emphasis of this report is on *identification* of geological and geomorphological properties that might be included on the World Heritage List. The World Heritage Centre, the World Heritage Committee and the IUCN should also encourage sharing of geological/ geomorphological *site management* experience. Bilateral arrangements between World Heritage properties with significant geological and geomorphological values, or networking of such sites linked through the internet, should be encouraged.

Recommendation 8: The concepts of managing geological and geomorphological heritage within WH sites should also be promoted more generally in the context of site management strategies for sites not inscribed for criterion viii. The *Operational Guidelines* to the *Convention* have recently been revised. During this revision process there was discussion concerning the requirement within World Heritage sites to manage heritage values not explicitly recognized through the *Convention*, i.e. heritage not specifically recognized through inscription on one or more of the recognized criteria. There was no agreement on this issue, but protection of natural heritage of **outstanding universal value** within a World Heritage Site cannot logically be separated from protection of all natural heritage within that site.

Recommendation 9: Geological/geomorphological World Heritage sites should be promoted widely as models to improve understanding of the conservation issues surrounding this aspect of the natural environment, to demonstrate the scientific, cultural and economic value of such heritage and to disseminate best management practice.

8. APPENDICES

Appendix 1: Geological Scope of Existing World Heritage Properties

Appendix 2: Current Approaches to Inventory and Evaluation of Geological Sites for Conservation

Appendix 3: Outstanding universal value and Comparative Analysis for Geological Sites

APPENDIX 1: GEOLOGICAL SCOPE OF EXISTING WORLD HERITAGE PROPERTIES

This appendix presents the current geological scope of properties inscribed on the World Heritage List at July 2005. It reports on the geological values within the 160 natural and 24 mixed properties inscribed on the list, and presents this analysis in three tables below.

Table 1: World Heritage properties with earth science features of outstanding universal value (provisional assessment)

Table 1 identifies the properties that IUCN considers to have been inscribed on the World Heritage List as having **outstanding universal value** for their earth science importance. The values are then assigned to one of more of the thirteen themes set out in Chapter 4 of this report.

This table suggests that 71 properties have been inscribed on the World Heritage List for **outstanding universal value** for the earth sciences. Within these 71 properties the breakdown within the thirteen themes is as follows (provisional figures):

Theme	Principal features of OUV	Possible features of OUV	Other significant features
Tectonic and structural features	**3**	1	3
Volcanoes /Volcanic systems	**13**	0	0
Mountain systems	**11**	4	9
Stratigraphic sites	**2**	0	0
Fossil sites	**11**	1	9
Fluvial /lacustrine and deltaic systems	**10**	4	6
Caves and karst systems	**7**	1	4
Coastal systems	**8**	2	8
Reefs, atolls and oceanic islands	**1**	1	2
Glaciers and ice caps	**6**	2	5
Ice Ages	**7**	6	6
Arid and semi-arid desert systems	**4**	0	3
Meteorite impact	**1**	0	0
	Note: figures do not sum as some properties are assigned to more than one theme.		

Technical note: Two points of context should be noted in reading Tables 1, 2 and 3:

1. Which properties are included in Table 1? Making the assessment of which properties to include is not entirely straightforward because of the changes in the wording of the World Heritage criteria:

Pre 1994: until 1994, earth science **outstanding universal value**s were included within the wording of criteria N(i) and N(ii). Whilst N(i) encompassed solely earth science values, the wording of criterion N(ii) contained elements of both earth science and biological values. Values attributed under criterion N(i) at this time are equivalent to the new criterion viii. IUCN has made a provisional assessment of the group of properties that were inscribed under criterion N(ii) but not N(i) prior to 1994, to identify those that demonstrate earth science features of **outstanding universal value**. These judgements are not definitive, and it is anticipated that the World Heritage Committee may wish to agree a reclassification of this group of properties as a whole into either criterion viii and/or ix of the newly renumbered set of criteria.

Post 1994: since 1994 earth science **outstanding universal value**s have been included within criterion N(i), and are equivalent to the values in new criterion viii.

2. Assignment to themes: In Table 1 where properties display values in more than one theme, it is not necessarily the case that different thematic values are at the level of **outstanding universal value** – for instance Macquarie Island is an oceanic island that displays exceptional tectonic features, and is therefore noted in both themes. However it is the tectonic features that provide the basis for its claim of **outstanding universal value**s.

In all the tables evaluation in this report is based on the summary descriptions available on the UNESCO website, and it is likely that more detailed analysis of properties would increase the range of themes represented, and the numbers of properties with values within each of the themes.

Table 2: World Heritage natural and mixed properties with significant earth science values, but which are inscribed on the World Heritage List for other reasons (provisional assessment)

Table 2 has been compiled by desk analysis of the other natural properties on the World Heritage List and selects those that appear to demonstrate a significant level of earth science interest, but not at the level of **outstanding universal value**. The table is an indicative list, and some judgements are easier to make than others. A provisional assessment has been made of the 13 thematic interests that each property displays. It should be noted that a significant number of properties inscribed under criterion N(iii) (equivalent to new criterion vii) have substantial earth science values.

The numbers of properties in Table 2 that lie within each theme are as follows:

Theme	Number of properties
Tectonic and structural features	0
Volcanoes /Volcanic systems	8
Mountain systems	5
Stratigraphic sites	0
Fossil sites	0
Fluvial /lacustrine and deltaic systems	20
Caves and karst systems	6
Coastal systems	10
Reefs, atolls and oceanic islands	11
Glaciers and ice caps	7
Ice Ages	1
Arid and semi-arid desert systems	2
Meteorite impact	0
	Note: figures do not sum as some properties are assigned to more than one theme.

Table 3: World Heritage natural and mixed properties with lesser earth science values (provisional assessment)

Table 3 sets out the remainder of the natural and mixed properties on the World Heritage List, which appear to demonstrate relatively few earth science features. Nevertheless earth science values are present at some level in all of these properties, and an assessment has again been made of the thematic interests that they represent.

Table 1: World Heritage properties with earth science features of outstanding universal value (provisional assessment)

Note. This table contains details of those properties inscribed on the World Heritage List (at 2005) with earth science features of outstanding universal value (see technical note on page 21). The values displayed by each property have been provisionally assigned to one or more of the 13 key earth science themes recommended in this report. The features within the properties are recognized using the following codes:

●	= principal feature(s) of **outstanding universal value**
●?	= possible features of **outstanding universal value**
(●)	= other features demonstrated by this property

WHS Name	Country 1	Country 2	Date of First Inscription	Criteria under which inscribed	Tectonic and structural features	Volcanoes /Volcanic systems	Mountain systems	Stratigraphic Sites	Fossil Sites	Fluvial /lacustrine and deltaic systems	Caves and karst systems	Coastal Systems	Reefs, atolls and oceanic islands	Glaciers and ice caps	Ice Ages	Arid and semi-arid desert systems	Meteorite impact
Galapagos	Ecuador		1978	N (i) (ii) (iii) (iv)		●							●?				
Nahanni National Park	Canada		1978	N (ii) (iii)			●?		(●)	●	(●)						
Yellowstone	USA		1978	N (i) (ii) (iii) (iv)		●	●?		(●)								
Dinosaur Provincial Park	Canada		1979	N (i) (iii)					●							(●)	
Everglades National Park	USA		1979	N (i) (ii) (iv)						●		(●)					
Grand Canyon National Park	USA		1979	N (i) (ii) (iii) (iv)				●	(●)	●							
Kluane/ Wrangell-St Elias/Glacier Bay/ Tatshenshini-Alsek	Canada	USA	1979	N (ii) (iii) (iv)			●		(●)	●?				●?			
Ngorongoro Conservation Area	United Republic of Tanzania		1979	N (ii) (iii) (iv)		●			●?	(●)							
Plitvice Lakes National Park	Croatia		1979	N (ii) (iii)							●						
Virunga National Park	Democratic Republic of the Congo		1979	N (ii) (iii) (iv)		●	(●)										
Durmitor National Park	Serbia and Montenegro		1980	N (ii) (iii) (iv)						●					(●)		
Great Barrier Reef	Australia		1981	N (i) (ii) (iii) (iv)									●				
Los Glaciares	Argentina		1981	N (ii) (iii)			●?		(●)					●			

WHS Name	Country 1	Country 2	Date of First Inscription	Criteria under which inscribed	Tectonic and structural features	Volcanoes /Volcanic systems	Mountain systems	Stratigraphic Sites	Fossil Sites	Fluvial /lacustrine and deltaic systems	Caves and karst systems	Coastal Systems	Reefs, atolls and oceanic islands	Glaciers and ice caps	Ice Ages	Arid and semi-arid desert systems	Meteorite impact
Mammoth Cave National Park	USA		1981	N (i) (iii) (iv)					(●)		●						
Olympic National Park	USA		1981	N (ii) (iii)			●			(●)		(●)		(●)			
Willandra Lakes Region	Australia		1981	N (i) C (iii)						(●)						●	
Río Plátano Biosphere Reserve	Honduras		1982	N (i) (ii) (iii) (iv)			(●)			●		(●)					
Tasmanian Wilderness	Australia		1982	N (i) (ii) (iii) (iv) C (iii) (iv) (vi)			●			●?	(●)	●?					
Tassili n'Ajjer	Algeria		1982	N (ii) (iii) C (i) (iii)												●	
Cape Girolata, Cape Porto, Scandola Nature Reserve and the Piana Calanches of Corsica	France		1983	N (ii) (iii) (iv)								●					
Great Smoky Mountains National Park	USA		1983	N (i) (ii) (iii) (iv)			●										
Pirin National Park	Bulgaria		1983	N (i) (ii) (iii)			●			●?	●?						
Sangay National Park	Ecuador		1983	N (ii) (iii) (iv)		●	(●)							●			
Talamanca Range-La Amistad Reserves	Costa Rica	Panama	1983	N (i) (ii) (iii) (iv)			●?			●?				●?			
Vallee de Mai Nature Reserve	Seychelles		1983	N (i) (ii) (iii) (iv)					**								
Canadian Rocky Mountain Parks	Canada		1984	N (i) (ii) (iii)			●		●	(●)	(●)			(●)			
Yosemite National Park	USA		1984	N (i) (ii) (iii)			●			(●)					(●)		
Huascaran National Park	Peru		1985	N (ii) (iii)			●			(●)					(●)		

WHS Name	Country 1	Country 2	Date of First Inscription	Criteria under which inscribed	Tectonic and structural features	Volcanoes /Volcanic systems	Mountain systems	Stratigraphic Sites	Fossil Sites	Fluvial /lacustrine and deltaic systems	Caves and karst systems	Coastal Systems	Reefs, atolls and oceanic islands	Glaciers and ice caps	Ice Ages	Arid and semi-arid desert systems	Meteorite impact
Central Eastern Rainforest Reserves (Australia)	Australia		1986	N (i) (ii) (iv)		●											
Giant's Causeway and Causeway Coast	United Kingdom		1986	N (i) (iii)		●						(●)					
Škocjan Caves	Slovenia		1986	N (ii) (iii)					(●)								
Gros Morne National Park	Canada		1987	N (i) (iii)	●		(●)		●			●		(●)			
Hawaii Volcanoes National Park	USA		1987	N (ii)		●											
Uluru-Kata Tjuta National Park	Australia		1987	N (ii) (iii) C (v) (vi)	●?											●	
Wet Tropics of Queensland	Australia		1988	N (i) (ii) (iii) (iv)						●		(●)					
Mosi-oa-Tunya/Victoria Falls	Zambia	Zimbabwe	1989	N (ii) (iii)						●							
Te Wahipounamu	New Zealand		1990	N (i) (ii) (iii) (iv)			(●)					●		(●)			
Tongariro National Park	New Zealand		1990	N (ii) (iii) C (vi)		●	(●)										
Shark Bay, Western Australia	Australia		1991	N (i) (ii) (iii) (iv)								●					
Fraser Island	Australia		1992	N (ii) (iii)								●					
Australian Fossil Mammal Sites (Riversleigh-Naracoorte)	Australia		1994	N (i) (ii)					●								
Canaima National Park	Venezuala		1994	N (i) (ii) (iii) (iv)	(●)		●			●							
Ha Long Bay	Viet Nam		1994	N (i) (iii)								●					
Carlsbad Caverns National Park	USA		1995	N (i) (iii)					(●)		●						

WHS Name	Country 1	Country 2	Date of First Inscription	Criteria under which inscribed	Tectonic and structural features	Volcanoes /Volcanic systems	Mountain systems	Stratigraphic Sites	Fossil Sites	Fluvial /lacustrine and deltaic systems	Caves and karst systems	Coastal Systems	Reefs, atolls and oceanic islands	Glaciers and ice caps	Ice Ages	Arid and semi-arid desert systems	Meteorite impact
Caves of the Aggtelek Karst and Slovak Karst	Hungary	Slovak Republic	1995	N (i)					(●)		●						
Messel Pit Fossil Site	Germany		1995	N (i)					●								
Lake Baikal	Russian Federation		1996	N (i) (ii) (iii) (iv)						●							
The Laponian Area	Sweden		1996	N (i) (ii) (iii) C (iii) (v)			(●)							●	(●)		
Volcanoes of Kamchatka	Russian Federation		1996	N (i) (ii) (iii) (iv)		●											
Heard and McDonald Islands	Australia		1997	N (i) (ii)		●							(●)	●			
Lake Turkana National Parks	Kenya		1997	N (i) (iv)					●	(●)							
Macquarie Island	Australia		1997	N (i) (iii)	●								(●)				
Morne Trois Pitons National Park	Dominica		1997	N (i) (iv)		●											
Pyrenees- Mont Perdu	France	Spain	1997	N (i) (iii) C (iii) (iv) (v)			●								●		
Desembarco del Granma National Park	Cuba		1999	N (i) (iii)							(●)	●					
Lorentz National Park	Indonesia		1999	N (i) (ii) (iv)	(●)		●					(●)					
Miguasha Park	Canada		1999	N (i)					●								
Ischigualasto/ Talampaya Natural Parks	Argentina		2000	N (i)					●							(●)	
Isola Eolie (Aeolian Islands)	Italy		2000	N (i)		●						(●)					
The Gulung Mulu National Park	Malaysia		2000	N (i) (ii) (iii) (iv)							●						
The High Coast	Sweden		2000	N (i)								(●)			●		

WHS Name	Country 1	Country 2	Date of First Inscription	Criteria under which inscribed	Tectonic and structural features	Volcanoes /Volcanic systems	Mountain systems	Stratigraphic Sites	Fossil Sites	Fluvial /lacustrine and deltaic systems	Caves and karst systems	Coastal Systems	Reefs, atolls and oceanic islands	Glaciers and ice caps	Ice Ages	Arid and semi-arid desert systems	Meteorite impact
Dorset and East Devon Coast	United Kingdom		2001	N (i)				●	●			●					
Jungfrau-Aletsch-Bietschhorn	Switzerland		2001	N (i) (ii) (iii)			(●)							●			
Monte San Giorgio	Switzerland		2003	N (i)					●								
Phong Nha-Ke Bang National Park	Vietnam		2003	N (i)							●						
Purnululu National Park	Australia		2003	N (i) (iii)	(●)											●	
Three Parallel Rivers of Yunnan Protected Areas	China		2003	N (i) (ii) (iii) (iv)	●		(●)			●	●			(●)			
Ilulissat Icefjord	Denmark		2004	N (i) (iii)										●			
Vredefort Dome	South Africa		2005	N (i)													●
Wadi Al-Hitan (Whale Valley)	Egypt		2005	N (i)					●							(●)	
West Norwegian Fjords	Norway		2005	N (i) (iii)								●			●		

** Vallee de Mai's values are identified as an example of evolutionary processes but in a modern setting, and do not fit into the earth science themes as identified.

Table 2: World Heritage natural and mixed properties with significant earth science values, but which are inscribed on the World Heritage List for other reasons (provisional assessment)

WHS Name	Country 1	Country 2	Date of First Inscription	Criteria under which inscribed	Tectonic and structural features	Volcanoes /Volcanic systems	Mountain systems	Stratigraphic Sites	Fossil Sites	Fluvial /lacustrine and deltaic systems	Caves and karst systems	Coastal Systems	Reefs, atolls and oceanic islands	Glaciers and ice caps	Ice Ages	Arid and semi-arid desert systems	Meteorite impact
Simien National Park	Ethiopia		1978	N (iii) (iv)			●										
Sagarmatha National Park	Nepal		1979	N (iii)			●							●			
Kahuzi Biega National Park	Democratic Republic of the Congo		1980	N (iv)		●											
Darien National Park	Panama		1981	N (ii) (iii) (iv)						●		●					
Kakadu National Park	Australia		1981	N (ii) (iii) (iv) C (i) (vi)						●		●					
Mount Nimba Strict Nature Reserve	Guinea	Cote D'Ivoire	1981	N (ii) (iv)			●										
Aldabra Atoll	Seychelles		1982	N (ii) (iii) (iv)									●				
Lord Howe Island Group	Australia		1982	N (iii) (iv)		●							●				
Wood Buffalo National Park	Canada		1983	N (ii) (iii) (iv)						●							
Iguazu National Park	Argentina		1984	N (iii) (iv)						●							
Lake Malawi National Park	Malawi		1984	N (ii) (iii) (iv)						●							
Goreme National Park and the Rock Sites of Cappadocia	Turkey		1985	N (iii) C (i) (iii) (v)						●							
Iguacu National Park	Brazil		1986	N (iii) (iv)						●							
St Kilda	United Kingdom		1986	N (ii) (iii) (iv) C (iii) (v)		●							●				
Kilimanjaro National Park	Tanzania		1987	N (iii)		●											
Mount Taishan	China		1987	N (iii) C (i) (ii) (iii) (iv) (v) (vi)			●										

WHS Name	Country 1	Country 2	Date of First Inscription	Criteria under which inscribed	Tectonic and structural features	Volcanoes /Volcanic systems	Mountain systems	Stratigraphic Sites	Fossil Sites	Fluvial /lacustrine and deltaic systems	Caves and karst systems	Coastal Systems	Reefs, atolls and oceanic islands	Glaciers and ice caps	Ice Ages	Arid and semi-arid desert systems	Meteorite impact
Sian Ka'an	Mexico		1987	N (iii) (iv)						●		●	●				
Henderson Island	United Kingdom		1988	N (iii) (iv)									●				
Hierapolis-Pamukkale	Turkey		1988	N (iii) C (iii) (iv)							●						
Meteora			1988	N (iii) C (i) (ii) (iv) (v)						●							
Nanda Devi National Park	India		1988	N (iii) (iv)			●							●			
Banc d'Arguin National Park	Mauritania		1989	N (ii) (iv)								●				●	
Cliff of Bandiagara (Land of the Dogons)	Mali		1989	N (iii) C (v)						●							
Mount Huangshan	China		1990	N (iii) (iv) C (ii)			●										
Tsingy de Bemaraha Strict Nature Reserve	Madagascar		1990	N (iii) (iv)						●	●						
Air and Tenere Natural Reserves	Niger		1991	N (ii) (iii) (iv)		●										●	
Danube Delta	Romania		1991	N (iii) (iv)						●							
Ujung Kulon National Park	Indonesia		1991	N (iii) (iv)		●						●					
Huanglong Scenic and Historical Interest Area	China		1992	N (iii)			●				●			●			
Jiuzhaigou Valley Scenic and Historic Interest Area	China		1992	N (iii)						●	●						
Wulingyuan Scenic and Historical Interest Area	China		1992	N (iii)						●	●						
Tubbatha Reef Marine Park	Philippines		1993	N (ii) (iii) (iv)									●				

WHS Name	Country 1	Country 2	Date of First Inscription	Criteria under which inscribed	Tectonic and structural features	Volcanoes /Volcanic systems	Mountain systems	Stratigraphic Sites	Fossil Sites	Fluvial /lacustrine and deltaic systems	Caves and karst systems	Coastal Systems	Reefs, atolls and oceanic islands	Glaciers and ice caps	Ice Ages	Arid and semi-arid desert systems	Meteorite impact
Donana National Park	Spain		1994	N (ii) (iii) (iv)						●		●					
Rwenzori Mountains National Park	Uganda		1994	N (iii) (iv)		●	●			●				●			
Gough Island Wildlife Reserve	United Kingdom		1995	N (iii) (iv)									●				
Waterton Glacier International Peace Park	Canada/USA		1995	N (ii) (iii)			●							●			
Belize Barrier-Reef Reserve System	Belize		1996	N (ii) (iii) (iv)									●				
Mount Kenya Nationa Park/Natural Forest	Kenya		1997	N (ii) (iii)		●								●			
East Rennell	Solomon Islands		1998	N (ii)									●				
Golden Mountains of Altai	Russian Federation		1998	N (iv)			●										
Atlantic Forest Southeast Reserves	Brazil		1999	N (ii) (iii) (iv)			●			●							
Greater St Lucia Wetland Park	South Africa		1999	N (ii) (iii) (iv)								●	●				
Mount Wuyi	China		1999	N (iii) (iv) C (iii) (vi)						●							
Puerto-Princesa Subterranean River National Park	Philippines		1999	N (iii) (iv)							●						
Kinabalu Park	Malaysia		2000	N (ii) (iv)			●								●		
The Greater Blue Mountains Area	Australia		2000	N (ii) (iv)			●			●							
uKhahlamba/ Drakensburg Park	South Africa		2000	N (iii) (iv) C (i) (iii)			●			●							
Alejandro de Humboldt National Park	Cuba		2001	N (ii) (iv)						●	●	●					

WHS Name	Country 1	Country 2	Date of First Inscription	Criteria under which inscribed	Tectonic and structural features	Volcanoes /Volcanic systems	Mountain systems	Stratigraphic Sites	Fossil Sites	Fluvial /lacustrine and deltaic systems	Caves and karst systems	Coastal Systems	Reefs, atolls and oceanic islands	Glaciers and ice caps	Ice Ages	Arid and semi-arid desert systems	Meteorite impact
Brazilian Atlantic Islands: Fernando de Noronha and Atol das Rocas Reserves	Brazil		2001	N (ii) (iii) (iv)									•				
Central Sikhote-Alin	Russian Federation		2001	N (iv)			•										
Natural System of Wrangel Island Reserve	Russian Federation		2004	N (ii) (iv)			•							•			
Shiretoko	Japan		2005	N (ii) (iv)								•					
Islands and Protected Areas of the Gulf of California	Mexico		2005	N (ii) (iii) (iv)								•					

Table 3: World Heritage natural and mixed properties with lesser earth science values (provisional assessment)

WHS Name	Country 1	Country 2	Date of First Inscription	Criteria under which inscribed	Tectonic and structural features	Volcanoes /Volcanic systems	Mountain systems	Stratigraphic Sites	Fossil Sites	Fluvial /lacustrine and deltaic systems	Caves and karst systems	Coastal Systems	Reefs, atolls and oceanic islands	Glaciers and ice caps	Ice Ages	Arid and semi-arid desert systems	Meteorite impact
Belovezhskaya Puschcha/Bialowieza Forest	Belarus	Poland	1979	N (iii)						●							
Ohrid Region with its Cultural and Historical Aspect and its natural environment	Former Yugoslav Republic of Macedonia		1979	N(iii)								●					
Tikal National Park	Guatemala		1979	N (ii) (iv) C (i) (iii) (iv)						●							
Garamba National Park	Democratic Republic of the Congo		1980	N (iii) (iv)						●							
Ichkeul National Park	Tunisia		1980	N (iv)						●							
Redwood National Park	USA		1980	N (ii) (iii)			●					●					
Djoudj National Bird Sanctuary	Senegal		1981	N (iii) (iv)						●							
Niokolo-Koba National Park	Senegal		1981	N (iv)						●							
Serengeti National Park	United Republic of Tanzania		1981	N (iii) (iv)						●							
Selous Game Reserve	United Republic of Tanzania		1982	N (ii) (iv)						●							
Taï National Park	Cote d'Ivoire		1982	N (iii) (iv)						●							
Comoe National Park	Cote d'Ivoire		1983	N (ii) (iv)						●							
Historic Sanctuary of Machu Picchu	Peru		1983	N (ii) (iii) C (i) (iii)			●										
Srebarna Nature Reserve	Bullgaria		1983	N (iv)						●							

WHS Name	Country 1	Country 2	Date of First Inscription	Criteria under which inscribed	Tectonic and structural features	Volcanoes /Volcanic systems	Mountain systems	Stratigraphic Sites	Fossil Sites	Fluvial /lacustrine and deltaic systems	Caves and karst systems	Coastal Systems	Reefs, atolls and oceanic islands	Glaciers and ice caps	Ice Ages	Arid and semi-arid desert systems	Meteorite impact
Mana Pools Natioan Park, Sapi and Chewore Safari Area	Zimbabwe		1984	N (ii) (iii) (iv)						●							
Royal Chitwan National Park	Nepal		1984	N (ii) (iii) (iv)						●							
Salonga National Park			1984	N (ii) (iii)						●							
Kaziranga National Park	India		1985	N (ii) (iv)						●							
Keoladeo National Park	India		1985	N (iv)						●							
Manas Wildlife Sanctuary	India		1985	N (ii) (iii) (iv						●							
Garajonay National Park	Spain		1986	N (ii) (iii)						●							
Dja Faunal Reserve	Cameroon		1987	N (ii) (iv)						●							
Manu National Park	Peru		1987	N (ii) (iv)			●			●							
Sundarbans National Park	India		1987	N (ii) (iv)						●		●					
Manovo-Gounda St Floris National Park	Central African Republic		1988	N (ii) (iv)						●							
Mount Athos	Greece		1988	N (iii) C (i) (ii) (iv) (v) (vi)			●										
Sinharaja Forest Reserve	Sri Lanka		1988	N (ii) (iv)						●							
Rio Abiseo National Park	Peru		1990	N (ii) (iii) (iv) C (iii)			●										
Komodo National Park	Indonesia		1991	N (iii) (iv)		●							●				
Thungyai-Huai Kha Khaeng Wildlife Sanctuaries	Thailand		1991	N (ii) (iii) (iv)						●							
Shirami-Sanchi	Japan		1993	N (ii)			●										

WHS Name	Country 1	Country 2	Date of First Inscription	Criteria under which inscribed	Tectonic and structural features	Volcanoes /Volcanic systems	Mountain systems	Stratigraphic Sites	Fossil Sites	Fluvial /lacustrine and deltaic systems	Caves and karst systems	Coastal Systems	Reefs, atolls and oceanic islands	Glaciers and ice caps	Ice Ages	Arid and semi-arid desert systems	Meteorite impact
Whale Sanctuary of El Vizcaino	Mexico		1993	N (iv)								•					
Yakushima	Japan		1993	N (ii) (iii)			•										
Arabian Oryx Sanctuary	Oman		1994	N (iv)												•	
Bwindi Impenetrable National Park	Uganda		1994	N (iii) (iv)						•							
Los Katios National Park	Colombia		1994	N (ii) (iv)						•							
The Virgin Komi Forests	Russian Federation		1995	N (ii) (iii)						•							
Mt Emei and Leshan Giant Buddha	China		1996	N (iv) C (iv) (vi)						•							
Okapi Wildlife Reserve	Democratic Republic of the Congo		1996	N (iv)						•							
W National Park of Niger	Niger		1996	N (ii) (iv)						•							
Cocos Island National Park	Costa Rica		1997	N (ii) (iv)									•				
The Sundarbans	Bangladesh		1997	N (ii) (iv)						•		•					
New Zealand Sub Antarctic Islands	New Zealand		1998	N (ii) (iv)									•				
Area de Conservacion Guanacaste	Costa Rica		1999	N (ii) (iv)						•		•					
Discovery Coast Atlantic Forest Reserves	Brazil		1999	N (ii) (iv)						•		•					
Ibiza, biodiversity and culture	Spain		1999	N (ii) (iv) C (ii) (iii) (iv)								•					
Peninsula Valdes	Argentina		1999	N (iv)								•					
The Laurisilva of Madeira	Portugal		1999	N (ii) (iv)						•							

WHS Name	Country 1	Country 2	Date of First Inscription	Criteria under which inscribed	Tectonic and structural features	Volcanoes /Volcanic systems	Mountain systems	Stratigraphic Sites	Fossil Sites	Fluvial /lacustrine and deltaic systems	Caves and karst systems	Coastal Systems	Reefs, atolls and oceanic islands	Glaciers and ice caps	Ice Ages	Arid and semi-arid desert systems	Meteorite impact
Western Caucasus	Russian Federation		1999	N (ii) (iv)			●										
Central Amazon Conservation Complex			2000	N (ii) (iv)						●							
Central Suriname Nature Reserve	Suriname		2000	N (ii) (iv)						●							
Noel Kempff Mercado National Park	Bolivia		2000	N (ii) (iv)													
Pantanal Conservation Area	Brazil		2000	N (ii) (iii) (iv)						●							
Cerrado Protected Areas: Chapada dos Veadeiros and Emas National Parks	Brazil		2001	N (ii) (iv)						●							
Uvs Nuur Basin	Mongolia	Russian Federation	2003	N (ii) (iv)						●							
Cape Floral Region Protected Areas	South Africa		2004	N (ii) (iv)						●		●					
Pitons Management Area	St Lucia		2004	N (i) (iii)		●											
Tropical Rainforest Heritage of Sumatra	Indonesia		2004	N (ii) (iii) (iv)			●			●							
Dong Phayayen-Khao Yai Forest Complex	Thailand		2005	N (iv)						●							
Coiba National Park	Panama		2005	N (ii) (iii) (iv)								●					

APPENDIX 2: APPROACHES TO INVENTORY AND EVALUATION OF GEOLOGICAL SITES FOR CONSERVATION

National Approaches

Many countries have national geoconservation programmes and these cover a wide range of approaches to inventory and documentation of the diversity of geological and geomorphological phenomena (see box for definitions). Dixon (1996) provides a summary of many of these national schemes, while European approaches are broadly canvassed by papers from the Third International ProGEO Symposium (Barrettino et al. 1999).

Terminology for geological conservation

Geodiversity

"The natural range (diversity) of geological (bedrock), geomorphological (landform) and soil features, assemblages, systems and processes. Geodiversity includes evidence for the history of the Earth (evidence of past life, ecosystems and environments) and a range of processes (biological, hydrological and atmospheric) currently acting on rocks, landforms and soils."
(Source: Hamilton-Smith 2000; Dixon 1996).

Geoconservation

"The conservation of geodiversity for its intrinsic ecological and heritage values."
(Source: Dixon 1996).

Geoheritage

"Those components of natural geodiversity of significant value to humans, including scientific research, education, aesthetics and inspiration, cultural development, and a sense of place experienced by communities."
(Source: Dixon 1996)

Earth Heritage

"The inheritance of rocks, soils and landforms (active and relict) and the evidence they contain that enables the history of the Earth to be unravelled."
(Source: Wilson, (ed.) 1994; Ellis et al. (eds.) 1996).

Such reviews of experience from around the world reveal two basic approaches to geodiversity or geosite inventory, referred to by Dixon (1996) as 'first order' inventories and 'second order' inventories respectively. First are those that are based primarily on existing information and are largely unsystematic in approach – the majority of natural schemes appear to fall into this category. Second, are the more systematic and objective processes of information gathering based on a classification system of some sort. Some examples of the systematic, 'second order' approaches are outlined in the following paragraphs to illustrate the breadth of methods and typologies used and the scope of coverage of geological heritage. Note that the cases chosen address the particular geological character and circumstances applying in the country concerned; they are not intended to be generic.

Republic of Ireland

Geological sites are selected on a thematic basis, using 17 themes intended to cover the full geological story of the country (Parkes et al. 1999), *viz:*

- Karst
- Precambrian to Devonian Paleontology
- Carboniferous to Pliocene Paleontology
- Precambrian and Dalradian geology
- Lower Paleozoic (Cambrian to Silurian) geology
- Devonian geology
- Carboniferous geology

- Permian to Tertiary geology
- Quaternary stratigraphy, including Pleistocene Paleontology
- Quaternary depositional landforms
- Quaternary erosional landforms
- Igneous
- Minerals and Mineralisation
- Landscapes and Landforms
- Groundwater
- Coasts, Rivers, Lakes
- Peat Bogs

Russia
Sixteen types of geological heritage are recognised nationally (Vdovets 1999; Karpunin, 1999), within a series of categories, *viz:*

- Paleontology
- Stratigraphy
- Ore litho-petrology
- Mineralogy
- Geomorphology, including hydrogeological
- Cosmogeny, including astroblemes
- Paleoenvironments
- Neotectonics
- Historic, e.g. survey and mining sites

Italy
Geosite inventories, such as those in the Abruzzo Region, use a seven-fold geological typology or category system (Massoli-Novelli et al. 1999), *viz:*

- Geomorphology
- Stratigraphy
- Tectonics
- Mineralogy and petrology
- Hydrogeology
- Paleontology
- Pedology

New Zealand
Has a 15-category geopreservation inventory system (Hayward 1989), *viz:*

- Landforms
- Caves and karst
- Quaternary volcanoes (2 classes)
- Fossil sites
- Mineral sites
- Earth deformation features
- Geothermal fields and features
- Igneous sites
- Metamorphic sites
- Structural sites
- Sedimentary sites
- Soil sites (2 classes)
- Geological history sites

Great Britain
Great Britain has one of the most comprehensive national geological inventory systems and one that is very firmly based strategically (Anon 1991; Ellis et al. 1996; Duff 1997). Known as the Geological

Conservation Review, the inventory and site selection process began in 1977 and has six major scientific and conservation objectives, as follows:

- Maintaining the network of Sites of Special Scientific Interest (SSSIs)
- Expanding the Regionally Important Geological/geomorphological Sites (RIGs)
- Developing new conservation techniques.
- Improving site documentation.
- Increasing public awareness.
- Developing international links.

To establish the representativeness of sites, the inventory methodology employs a series of "subject blocks" within a thematic framework, with the blocks subdivided into "networks" or natural groupings of geological features and scenarios. In all, 100 subject blocks are identified under seven themes, as follows:

Earth heritage themes	No. of subject blocks
Stratigraphy	35
Paleontology	16
Quaternary Geology	16
Igneous petrology	6
Structural and metamorphic petrology	10
Mineralogy	7
Geomorphology	10

It is intended that the results of the inventory be published progressively in a series of some 50 volumes arranged on a thematic basis. For example, the section on paleontology recognises seven themes, *viz:*

- Reptiles
- Invertebrates
- Mammals
- Paleobotany (2 classes)
- Fish (2 classes)

The section on geomorphology is divided into six themes, *viz:*

- Caves
- Coastal (2 classes)
- Fluvial
- Karst
- Mass movement

International Approaches

The Geosites Program: The most comprehensive global inventory of geological sites is the Geosites Program. Begun in 1996, and operating under the IUGS until 2004, Geosites involves development and co-ordination of an international database from systematic inventory of the world's geological resources. The primary objective of the program is to provide a factual basis to support national and international initiatives to protect geological resources for research and education. While the program has a somewhat limited focus on research and education, an intended end use of the database is to provide advice to the IUGS, and other bodies such as UNESCO, on priorities for conservation of geological sites in a global context. In this sense, Geosites is of potential benefit to the World Heritage Program.

Geosites relies on systematic inventory of geological phenomena. Countries are encouraged to adopt their own stratigraphic, tectonic or other frameworks for this purpose. Geosites is developing overarching criteria and principles to guide the objective selection of the best geological sites in compiling the international database. The key criteria are as follows:
Representativeness

The focus is on contextual relevance rather than viewing sites in isolation. Emphasis is given to identifying sites within spatial and genetic patterns of geological phenomena.

Uniqueness

This may be determined using either quantitative measures such as size, frequency of occurrence, concentration and rates of change; or qualitative measures including assemblages, special combinations of features, spatial indicators (locations and geographical patterns) or temporal indicators (first/last appearances and occurrences, youngest/oldest features).

Suitability for correlation

The most valuable sites are those allowing international correlations, for example biozonal type localities. Also valuable are sites demonstrating spatial or temporal connections between different categories in a tectonic or stratigraphic framework.

Complexity and geodiversity

Where representativeness is considered equal, then sites of greater complexity or diversity are given higher rank.

There are in addition two secondary criteria:

Degree of research/study

The focus is on sites that have a strong research underpinning, especially involving multi-disciplinary studies.

Site availability and potential

This is a measure of the accessibility of a site and the long-term opportunities for research and educational activities.

Several further principles have been established to guide geosite selection. Thus, Geosites avoids rigid classification systems and a strict adherence to ensuring comprehensive representation of geological phenomena. Classification is regarded as a sterile artefact, which detracts from a focus on elements of geology, while representativeness, of itself, can induce repetition, and inclusion of the commonplace or unremarkable features at the expense of recognizing salient events and places. Emphasis is, therefore, given to development of thematic frameworks that enable sites to be selected as evidence of major geological events or processes.

Finally, a generic framework is offered as a basis for applying the thematic approach, and from within which to identify key sites. The framework is as follows:

- Stratigraphy
- Quaternary
- Phanerozoic
- Protozeroic
- Archaean
- Paleo-environment
- Paleontology
- Igneous, metamorphic and sedimentary petrology, textures and structures.
- Mineralogy/economic geology
- Structure
- Geomorphological features/erosional and depositional processes/landforms/landscapes.
- Astroblemes
- Continental/oceanic scale features/tectonic plate relations and terrains

- Submarine geology
- Historic geology/geological science developments (eg) classic sections used in the development and understanding of the geological sciences.

UNESCO Geoparks Program

Another major international initiative for geological protection, complementing the IUGS Geosites program, is the UNESCO Geoparks Program (Weighell 1999). Philosophically founded in the 1991 Digne "Declaration of the Rights of Memory of the Earth", Geoparks would be a global series of geological sites intended to integrate the preservation of geological heritage and sustainable resource and economic development. In this respect Geoparks are considered to be in harmony with the objectives of Biosphere Reserves under the UNESCO Man and the Biosphere Program (MAB). They are also regarded as complementary to the World Heritage List, in providing an appropriate mechanism for recognizing internationally important sites identified from both national and international geological inventories. Draft guidelines reveal the multiple roles and purposes for Geopark establishment and management (Anon. 2000 a). Six principles are specified for recognizing Geoparks, relating to their size, composition, socio-economic objectives, conservation objectives, education and research objectives, and to legal status and sovereignty issues. A further six criteria are provided for site nomination relating to composition (number of geosites), promotion of socio-economic development, conservation of geodiversity, education and research role, management planning, and management authority and co-operation.

The Geoparks program incorporates a highly innovative policy mandate in giving recognition to the interests of social advancement and economic resource development. Clearly, however, the role and purpose of geosite protection fulfilled by Geoparks are different from those of the *World Heritage Convention*. The rationale underscoring the relationship between Geoparks and World Heritage sites is that the World Heritage List is only likely to include a limited number of sites of primary geological or geomorphological interest. The necessarily selective nature of World Heritage listing cannot, therefore, be regarded as adequate for recognizing the full range of globally significant geological sites.

Assessing the significance of geological sites

In the course of conducting inventories of geosites, at national and international scales, attention is also given to assessing the conservation significance of sites. Often this is done as part of a more comprehensive environmental resource inventory for the purposes of protected area system planning. Methods adopted for assessing significance normally include establishing a set of criteria, but approaches vary in respect of the criteria used and the relative weighting given to any particular criterion.
As a general observation, the criteria used tend to be somewhat crude and contain an element of subjectivity. Thus, a greater emphasis may be given to aesthetic aspects of size and scale of a feature, its prominence, the juxtaposition of different features and the diversity displayed at a site. Some approaches, particularly in Europe and in the IUGS Geosites Program, which have placed particular emphasis on research and education values, have been labelled 'utilitarian' (Dixon 1996). Other approaches are broader philosophically and take account, for example, of site management priorities such as vulnerability to threat of loss or disturbance. Other approaches are attempting a more objective assessment by developing typologies of classes of geological phenomena against which examples can be compared to determine whether they fall above or below a threshold of significance. Such approaches may utilize the canvassing of expert opinion, possibly using a Delphi scoring system as was done in the case of assessing the World Heritage values of the world's Subantarctic islands (Dingwall 1985).

Inevitably, assessment of significance has addressed the concepts of outstanding and representative features. Dixon (1996) offers helpful definitions for geological features and sites, as follows:

Outstanding Geological Feature
"One that exemplifies an earth process through a feature or assemblage which is rare, unique, an outstandingly expressed example of its type, or otherwise of special scientific, cultural or aesthetic importance."

Representative Geological Feature
"May be either rare or common, but is considered significant as a well-developed or well-exposed example of its type."

Some examples of national approaches to assessing the conservation significance of geosites are as follows:

In Poland (Alexandrowicz et al. 1999) significance criteria include:

- Variety of geological forms and structures, i.e. richness.
- Scarcity or uniqueness.
- Distinctiveness of relief features
- Aesthetics and cultural connections.

In Switzerland (Grandgirard 1999) a list of 401 geological sites of national significance has been compiled using the criteria of:

- Integrity
- Rarity
- Scientific value
- Ecological value
- Scenic value

In the United Kingdom's Geological Conservation Review process for selecting Sites of Scientific Interest (SSSIs) (Ellis et al. 1996) emphasis is given to three primary criteria:

- Research
- Education
- Historic geological context;

Five secondary criteria relating to the exceptional features:

- Exceptional fossil preservation
- Exceptional development of a feature
- Spectacular and visually striking phenomena
- Monumental qualities, i.e. icons
- Extraordinary richness or diversity;

Consideration is also given to the international importance of a site or feature:

- Reference (standard) localities
- Type localities
- Historic significance, as first discoveries or first studies etc.

APPENDIX 3: OUTSTANDING UNIVERSAL VALUE AND COMPARATIVE ANALYSIS FOR GEOLOGICAL SITES

This Appendix provides guidance on the concept of **outstanding universal value** (OUV) as it applies to geological interests, and more information on Comparative Analysis.

A3.1 The Concept of outstanding universal value for Natural World Heritage

The concept of **outstanding universal value** was discussed at an expert meeting in Kazan, Russian Federation in April 2005. Full texts of the papers from this meeting are available via the UNESCO World Heritage Centre. The meeting noted that the definition of **outstanding universal value** in the *Operational Guidelines* to the *World Heritage Convention* (2005 version) is:

> *"cultural and/or natural significance which is so exceptional as to transcend national boundaries and to be of common importance for present and future generations of all humanity. As such, the permanent protection of this heritage is of the highest importance to the international community as a whole."* (Section II. A. paragraph 49)

OUV is thus the central construct of the *Convention* and IUCN considers the following issues are relevant in defining its meaning:

- Outstanding: For properties to be of OUV they should be exceptional. IUCN has noted in several expert meetings that: "the *World Heritage Convention* sets out to define the geography of the superlative – the most outstanding natural and cultural places on Earth" (Thorsell, 1997);

- Universal: The scope of the *Convention* is global in relation to the significance of the properties to be protected as well as its importance to all people of the world. By definition properties cannot be considered for OUV from a national or regional perspective; and

- Value: What makes a property outstanding and universal is its "value" which implies clearly defining the worth of a property, ranking its importance based on clear and consistent standards, and assessing its quality.

IUCN has provided the following advice in relation to the definition of **outstanding universal value** in relation to the natural criteria, as defined in Paragraph 77 of the *Operational Guidelines*:

Criterion (vii): Contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance

IUCN's assessment of OUV considers the following: Two distinct ideas are embodied in this criterion. The first, 'superlative natural phenomena', can often be objectively measured and assessed (the deepest canyon, the highest mountain, the largest cave system, the highest waterfall, etc.). The second concept, that of 'exceptional natural beauty and aesthetic importance' is harder to assess and evaluation tends to be more subjective. A total of 114 properties have been inscribed in the WH List under this criterion, most commonly in association with other criteria. The nature of this criterion is that the types of properties that are proposed for inscription will have comparable sites distributed on a world-wide, rather than regional basis, so standards applied under this criterion will need to meet a global standard of proof. This fact distinguishes the application of the aesthetic element of this criterion from those factors relevant to the consideration of cultural landscapes. IUCN's decisions in relation to this aspect are based on comparison with properties previously inscribed by the WH Committee under this criterion and, to the extent possible, they also involve a comparison of measurable indicators of scenic value. Following discussion on this in the context of nominations considered at the 28th session of the WH Committee, IUCN is currently undertaking additional work to better guide its assessment of this criterion.

Criterion (viii): 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

IUCN's assessment of OUV considers the following: The assessment framework for this criterion is global, reflecting both the global distribution of geomorphological features and the world-wide perspective required to encompass the representation of the 4.6 billion years of Earth history, address the evolution of life on Earth as well as the changes in the geography of the planet. In view of the specialized nature of some geological nominations, IUCN takes advice from geological experts, and is developing its contacts within international geoscience groups to strengthen the review base for geological properties. This criterion involves four distinct, although closely linked, natural elements relevant to geological and geomorphological science:

(i) Earth's history - This subset of geological features includes phenomena that record important events in the past development of the planet such as the record of crustal dynamics, the genesis and development of mountains, plate movements, continental movement and rift valley development, meteorite impacts, and changing climate in the geological past. Properties that may be considered for inscription on the WH List under this category would primarily involve places where major discoveries that have been in relation to our overall understanding of earth processes and forms as revealed by rock sequences or associations rather than fossil assemblages.

(ii) The record of life - This subset includes paleontological (fossil) sites. For evaluating such nominations IUCN has developed a checklist which is included in the box below.

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, and 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: *Earth's Geological History – A contextual Framework for Assessment of World Heritage Fossil site nominations*, Wells, 1996.

(iii) Significant on-going geological processes in the development of landforms - Geomorphological properties record current geological processes and their relationship to landforms and landscapes (or physiography). This subset of criterion (viii) features represents active geomorphological processes such

as those associated with glaciers, mountains, deserts, active volcanoes, rivers and deltas, island and coasts.

(iv) Significant geomorphic or physiographic features **-** This subset includes landforms that are the products of active processes, and is intimately linked with the consideration of processes listed above. This group also includes features resulting from earlier or long-standing periods of activity, such as relict glacial landforms; extinct volcanic systems; and karst features. These features may sometimes also be considered in relation to the application of criterion (vii), in view of the aesthetic quality of some spectacular landforms.

Criterion (ix): Be outstanding examples representing significant ongoing ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals.

IUCN's assessment of OUV considers the following: The assessment of this criterion depends on the scientific knowledge and understanding of Earth's ecosystems and the ecological and biological processes associated with their dynamics. To assess this criterion in an objective manner IUCN and partners have developed a number of *global thematic studies* (on forests, wetlands, marine and coastal areas, mountains, small island ecosystems, and boreal forests) that have guided IUCN's evaluation of this criterion. Further studies continue to be carried out as funding allows.

Criterion (x): 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.

IUCN's assessment of OUV considers the following: This criterion is associated with one of the core competencies of IUCN. In assessing this criterion, IUCN draws on expertise in its Commissions (with more than 10,000 expert members worldwide) and key IUCN members such as BirdLife International, WWF, Conservation International (CI), and The Nature Conservancy (TNC). There are a range of tools available to assess this criterion, including the IUCN Red List, Centres of Plant Diversity, Endemic Birds Areas of the World, the CI's Biodiversity Hotspots and WWF's Global 200 Ecoregions for Saving Life on Earth.

A3.2 The Role of Global Comparative Analysis in Assessing OUV for Natural Properties

In assessing the OUV concept, and in parallel to evaluating the criteria for which a property is nominated, IUCN addresses the question: how does the nominated property compare with other similar properties at the global level? Answering this question requires (i) the application of a global classification system and (ii) a comparison of the nominated property with other WH properties and protected areas within the same or a similar global context; in other words undertaking a Global Comparative Analysis as required under the *Operational Guidelines*, Section III.A.3, paragraph 132.3.

(i) A global classification system

In relation to criteria (ix) on ecological processes, and (x) on biodiversity, IUCN uses two global systems to classify properties:

(a) the framework provided by Miklos Udvardy in "A Classification of the Biogeographical Provinces of the World" , published in 1975 and updated in 1982; and
(b) internationally recognised global classification and prioritisation systems for natural habitats and ecosystems.

The Udvardy Classification System: This classification system defines eight Biogeographical Regions, which are further divided into 14 Biomes and 193 Biogeographic Provinces, with provinces broadly corresponding to established and recognised floristic regions of botanists and faunal provinces of zoologists. This System of Realm and Biome classification has proved a very effective framework for assessing natural and mixed WH properties and is the basis for IUCN Analysis of the World Heritage List. It has helped identify that natural and mixed properties on the WH List cover almost all biogeographic regions, biomes, and habitats of the world with a relatively balanced distribution. The biomes most

commonly found in World Heritage properties are Mountains, Humid Tropical Forests, Tropical Dry Forests and Mixed Island Systems. However, there are major gaps in the WH coverage of the following biomes: Tropical Grassland/Savanna; Lake Systems; Tundra and Polar Systems; Temperate Grasslands; and Cold Winter Deserts.

Other Global Classification and Prioritisation Systems: The Udvardy system will continue to be important for the future assessment of natural and mixed WH properties. However, it has a number of limitations. Its use by IUCN is therefore complemented by other classification and prioritisation systems in the evaluation of natural and mixed WH properties. These include: the IUCN/SSC Habitat Classification System, WWF Ecoregions, Conservational International Biodiversity "Hotspots", BirdLife International Endemic Bird Areas, and IUCN/WWF Centres of Plant Diversity. These globally recognised systems help prioritise properties of global importance, of OUV. The IUCN Analysis of the WH List (WHC-04/28COM INF13), by using the above methodology to analyse the current coverage of natural WH properties, provides a list of 20 key areas with potential for new natural and mixed properties of OUV.

In this context it should be stressed that whilst the *Operational Guidelines* of the *Convention* call for a balanced, representative and credible WH List, it was never intended that the List should ensure complete "representivity" of all the Earth's numerous ecosystems and habitats, which is the role of national, regional and other international protected area systems and instruments, for example the UNESCO Biosphere Reserve Programme. Thus, global classification and prioritisation systems should be seen as tools to apply the OUV test and not as targets to achieve representivity of all Earth's ecosystems.

In relation to properties nominated under criterion (viii), for geological properties, these can be assessed through existing international geological and geomorphological classifications, globally significant stratotypes, global scale geo-processes past and present, and combinations of different genesis and history found in a locality. The WH Committee has emphasised particularly strongly the need for properties nominated under this criterion to include a thorough global comparative analysis.

The assessment of criterion (vii), for natural phenomena and beauty, as noted in section 3.1, is difficult to correlate to an international classification system. Properties nominated under this criterion may therefore require only the comparison with other similar properties as outlined below.

(ii) Comparison with other similar properties

According to the *Operational Guidelines* (Section III.A.3, paragraph 132.3) the comparative analysis of the nominated property should be done in relation to similar properties, whether or not on the World Heritage List, both at the national and international levels. The comparative analysis should explain the importance of the nominated property in its international context by comparing it to other similar properties. There are two basic requirements that flow from this concept: (1) The comparative analysis needs to be global in scope, thus comparing the property with similar properties that exist around the world based, where possible, on a global classification system, and; (2) The nominated property should be compared not only with properties already inscribed on the WH List but also with other similar properties worldwide.

While a Global Comparative Analysis is an integral part of the nomination dossier it should be seen as an important step to be undertaken by the State Party before the property is nominated. Even at the time of including a property on the Tentative List, States Parties are encouraged to carry out a brief Comparative Analysis. In the opinion of IUCN, the quality of the Global Comparative Analyses in nomination documents needs to be greatly improved. To this end IUCN is currently preparing a *Resource Manual* on how to prepare high quality nominations for natural properties which will provide additional guidance on how to prepare these, including examples from nominations considered to demonstrate "best practice" in relation to this issue.

A3.3 Geomorphological Features and Processes

A key subset in the suite of **outstanding universal value**s to be considered in World Heritage listing relates to ongoing processes in geological development and the resultant landforms or physiographic features. Thus, the focus is on the geomorphological development of landforms and landscapes. This is often inextricably linked to biological development and environmental evolution, since climatic elements may be a common controlling factor in each of these cases.

In geoconservation a distinction can be made between geological sites, which are primarily of value in scientific terms as a record and manifestation of past processes in Earth evolution, and geomorphological sites, which have their greatest value in recording current geological processes and their relationships to landforms and landscapes (or physiography).

The question of where soils fit in this process deserves some discussion here. Soils are often included within the definition of geodiversity. Whether or not this is appropriate is an equivocal issue, and one that lacks any rigorous debate or any consistency in approaches to geoconservation. Soils are, in essence, living organic bodies that lie between, and demonstrate the integration of, the physical and biological realms in the landscape. Soils *per se* have received little attention within the protected areas profession, and it is rare to find protected areas devoted specifically to protection of soils and/or soil features. The New Zealand geopreservation inventory is a rare case in which a soil category is included (Hayward 1985). Dixon (1966) believes that this may be a consequence of the strength of the international soil conservation movement, which has its focus on the utilitarian values of soils, i.e. agriculture, horticulture, farming, forestry etc. Soils are not singled out for attention as components of natural heritage under the *World Heritage Convention*, and it is highly unlikely that sites would be either nominated or inscribed primarily for their soil values. For this reason, soils are not discussed in any detail in this report.

From international experience it is evident that landform processes and features have generally received less attention than geological features in the identification assessment and conservation of geosites. Ironically, however, in some national geological inventories geomorphology is a significant, if not predominant player. For example, the national geological inventory in Finland is restricted to one principal landform type, eskers (elongated sedimentary features built by rivers associated with continental ice sheets), which are given priority because of their multiple-use values including gravel extraction, conservation and recreation (Gonggrijp 1992). In Poland, national geosite inventory and protection has resulted in the registration of some 40 Geological Reserves and 1,340 Inanimate Nature Reserves, of which some 900 are individual glacial erratics (boulders transported and deposited by ice sheets and glaciers (Alexandrowicz 1993). The comprehensive, systematic inventory of geological phenomena in Australia is restricted to cave and karst features, compiled as a karst atlas (Kiernan 1995).

In noting that national inventories of active, ongoing geomorphological processes are rarely attempted, Dixon (1996) points out that where such inventories exist they are usually biased toward relict landforms and features, often adopting a limited reductionist approach. He stresses, as does Hamilton-Smith (2000) in discussing karst phenomena, that geomorphological protection requires an holistic approach that includes entire functioning systems. Thus, in protecting a cave system it is also necessary to protect the hydrological catchment (watershed) above the caves and all headwaters feeding into them. The same is true in protecting wetland systems such as lakes and estuaries. The concept of integrity within the *Operational Guidelines* for natural properties in the World Heritage network captures the importance of this concept well. However, one consequence of considering large systems is that geomorphological processes and features are usually best expressed over extensive areas rather than at sites. In turn, this means that representing geomorphological processes and features in World Heritage areas may best be achieved through a landscapes approach rather than one which focuses on small discrete sites.
Many widely differing approaches to representing the entire manifestation of geomorphic processes and forms can (and have) been followed. "Taxonomic"-type listings of phenomena are commonly adopted for scientific and/or academic purposes, and these come in a bewildering array of types in terms of their detailed structure. Such expansive typologies of classes of geomorphic phenomena are useful for characterizing the entire manifestation of specific landform types.

A3.4 Examples of Comparative Analysis for Geological Sites

As noted above rigorous comparative analysis is an essential requirement of World Heritage nominations, in order to establish a clear case for a site to be recognized as of **outstanding universal value**. The best source of information on comparative analysis is the body of case-law and in particular the comparative analyses of successful nominations. It is important to be clear on the nature of the values that are the basis for the comparison, and then to test against the bench-marks that have been established as sufficient for the World Heritage List. Such values might include:

- Presence of classic exemplars of those geological features that make a site important;
- Level of research interest and activity, both past and ongoing, including the degree of documentation in the scientific literature;
- Opportunities provided for use as a field 'laboratory' for research, monitoring and education;
- Significance for development of geological theory and understanding;
- Range of geological time covered by geological and geomorphological features; and
- Accessibility for research and other public uses.

For natural properties of geological significance the most comprehensive comparative analysis so far undertaken is that for Miguasha Park in Canada, a fossil site of Devonian age (Cloutier et al. 1998). The innovative, science-based methodology adopted is regarded by IUCN as a model approach worthy of wider adoption in the natural site evaluation process. A threefold method is used, as follows:

- Derive assessment criteria – these use as a basis the checklist of 10 questions developed by IUCN for evaluating the paleontological significance of fossil sites along with the nine recommended criteria of Wells (1996) for establishing the World Heritage standing of a fossil site. From these, seven generic criteria were derived for addressing the relative significance of sites, *viz:* vertebrate diversity; faunal representativeness; evolutionary representativeness; environmental representativeness; paleobiological representativeness; quality of fossil preservation; abundance of specimens.

- Select key sites to be evaluated – from bibliographic research and expert consultation a total group of 61 sites of the world's Devonian vertebrate fossils was selected. This total was reduced to 15 key sites by eliminating all sites that failed to meet at least one of five specific key qualifications in terms of their fossil context, *viz:*

  More than 10 vertebrate species; more than three major groups of fishes; more than one environmental component; macro remains of vertebrates; more than 100 vertebrate specimens.

- A score-based assessment – the 15 sites were assessed using a scoring system that awarded either an arbitrary score or an absolute score based on actual numbers. The result gave an overall rating that placed Miguasha first in seven of the 10 significance categories assessed, and either second or third placing in the remaining three categories. It established Miguasha as the outstanding representative of the world's Devonian fossil sites for demonstrating the origin of fishes.

The method used, though systematic and objective, is not without its problems and weaknesses. Among the problems are how to decide on what features or characteristics to use in the analysis, and how to establish a truly objective scoring system. The inherent weaknesses are common to any fossil site assessment, and recognize that it is the current state of knowledge about sites that is being assessed, not the actual biodiversity of the site, for example. Moreover, the taxonomic diversity recorded may reflect the scientific effort, with the best knowledge often focused on more attractive or interesting animal groups, for example. These deficiencies are noted also by Wells (1996).

The ten-fold IUCN criteria checklist for fossil site assessment was also used to good effect in a comparative analysis included in the nomination of the Dorset/East Devon Coast property by the United Kingdom. Twelve fossil sites or interests within the property were systematically rated against the IUCN criteria. Overall, the property was ranked highly in all the 10 categories assessed, but particularly in respect of the long geological time period represented (almost the full 200 million years of the Mesozoic Era); the rich diversity of fossil assemblages; the exceptional quality of preservation of specimens; and the paramount international significance of the site. The property is also revealed as having a unique

status in the history of geological science, with a reputation of over more than 200 years as being among the world's best sites for geological enquiry with thousands of scientific documents produced.

Hamilton-Smith (2000) suggest adapting the IUCN fossil site assessment checklist for evaluating karst sites. He also draws from work on hierarchical frameworks of karst ecosystems (e.g. Kiernan, 1995; Langer and Kolm, 2000) to provide a checklist of karst characteristics to use as the basis of comparative assessment of karst sites. Key elements in this checklist are:

Overall context of the karst system
- geographical location
- lithology
- structure and stratigraphy
- geomorphic history

Landform geodiversity
- depressions (dolines, poljes)
- cones and towers
- karren
- hydrological features
- depositional landforms

Groundwater systems and meteorology
- flows, springs, sinks
- microclimates

Subterranean Landforms (caves)
- e.g. genetic types of cave

Cave contents
- sediments
- speleothems
- fossils etc.

Biodiversity
- surface and subterranean biota
- speciation, adaptation, endemism.

Human occupation
- residence
- cultural values
- recreation/tourism
- pollution and hazards etc
- research and education

Condition and integrity
- damage
- modification
- management
- monitoring and environmental control

The case of the High Coast of Sweden nomination required comparison among world sites demonstrating isostatic rebound (uplift) of the earth's crust following Pleistocene-age continental glaciation. Only one other global site was found to be comparable, centered on Hudson Bay in Northern Canada. The two sites are essentially comparable, having experienced a total post-glacial uplift above present sea level of approximately 280m, and both areas are continuing to rise at some 8-10 mm/year. However, the Swedish High Coast was assessed as the world's best illustration of processes accompanying the growth and recession of a continental ice sheet and its effects on glacial landform evolution because:

- Its steeper relief confines relict shorelines to a narrow coastal zone
- Biological affinities with geological history are more starkly displayed
- The warmer present climate provides a greater diversity of biotypes
- It is more extensively studied and is a type-area for research and scientific understanding of isostasy
- There is a long period of human occupation with an abundant archaeological record.

This case demonstrates that the assessment process for geological site nominations may also need to take account of the natural associations among biological and human (cultural) phenomena and conservation values, and not be confined solely to geological values.

The example of the Aeolian Islands volcanoes site in Italy demonstrates the significance for World Heritage inscription ascribed to geological reference areas, the classical representation of landforms and the importance of sites for the history of geological science. The Aeolian Islands are volcanic in origin, and are included among the more than 1,300 active volcanoes in the world, and the more than 20 existing World Heritage sites with active or dormant volcanoes. As an archipelago, the site is comparable with two other World Heritage natural sites – the Galapagos Islands and Hawaiian Islands. The key attributes of the Aeolian Islands considered of sufficient universal scientific merit to justify World Heritage listing of the site were:

- The volcanoes here are among the earliest ever studied and documented so have international significance in the science of vulcanology
- Volcanoes here have given their name to two basic types of volcanic eruption – Vulcanian and Strombolian
- The volcanoes are classical, text-book examples of their type and the site provides in microcosm a 'laboratory' for the study of volcanic phenomena.

More information on comparative analyses for World Heritage sites is available from the UNESCO World Heritage Centre, most readily through examination of the evaluation reports of the advisory bodies which are available through the UNESCO World Heritage website (whc.unesco.org).

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