SERIES

Geoheritage 1. Geodiversity: A New Paradigm for Valuing and Conserving Geoheritage

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SUMMARY
The term 'geodiversity' was first used in 1993 as the geological equivalent of biodiversity. It has gained in international acceptance and usage in recent years, and now warrants the status of a geological paradigm. Geodiversity forms the basis for the selection of geoconservation sites, which should be chosen to represent the geodiversity of a country, province or region. The objectives and methods of geoconservation vary, depending on which element of geodiversity is being considered. For example, the formal protection of static geological and geomorphological sites needs to be supported by legislation, but geoconservation of landscapes, soils and physical processes in the wider landscape is best promoted through both, policy and partnership approaches.

SOMMAIRE
Le terme "géodiversité" a été utilisé la première fois en 1993 comme équivalent géologique du terme biodiversité. Il a été accepté au niveau international ces dernières années, et c'est maintenant un paradigme géologique. La géodiversité constitue le critère de base de sélection de sites de géoconservation représentant la géodiversité d'un pays, d'une province ou d'une région. Les objectifs et les méthodes de géoconservation varient selon l'élément de géodiversité considéré. Par exemple, la protection en l'état de sites géologiques et géomorphologiques doit être faite par législation, alors que la géoconservation de paysages, de sols et de processus physiques au sein d'un cadre panoramique plus large est plus efficace par une approche intégrée de règlements et de partenariats.

INTRODUCTION
My book entitled *Geodiversity* (Gray 2004) began by inviting readers to consider what the world would be like if it had no diversity of rocks, soils, topography, physical processes, etc. Fortunately, Planet Earth is not a perfect sphere composed of a single rock and soil type. It is hugely diverse in terms of its geological materials, its landforms, its physical processes and its fossil record. Viewing the planet in terms of this diversity, and the utilisation of this diversity by human societies throughout history enriches our appreciation of the values of the natural world and of our geoheritage. Geodiversity ought to have been a key theme of the International Year of Planet Earth!

Biodiversity (biological diversity) is the variety of living nature. As a concept, it came to prominence through the international adoption of the Convention on Biodiversity at the Earth Summit, in Rio de Janeiro in 1992. It promoted the idea that the world is biologically diverse, that there are significant threats to this biological diversity, and that there is, therefore, a need to take action to conserve it. It quickly became obvious to several geoscientists that there must be an equivalent to biodiversity to describe the variety of non-living or abiotic nature. And so, in 1993, the first usage of the term 'geodiversity' is found in publications from Germany and Australia (Wiedenbein 1993; Sharples 1993; see Gray 2008). Thus, several geologists quickly realized that it is possible to consider geology (including geomorphology) in much the same way as biology, viz. that Planet Earth is geologically very diverse, that this diversity is valuable but threatened, and that there is a need to conserve it.

Geodiversity has been defined as, *"the natural range (diversity) of geological (rocks, minerals, fossils), geomorphological (landform, processes) and soil features. It includes their assemblages, relationships, properties, interpretations and systems"* (Gray 2004, p. 8). At present, there are about 5000 named minerals, some of which are extremely rare and could easily be lost; in turn, these minerals combine to form thousands of named rock types. Hundreds of thousands of fossil species have been discovered and probably thousands more remain to be uncovered. There are 19 000 named soil series in the USA alone. In addition to this, there is a huge diversity of physical processes (e.g. fluvial, coastal, glacial, periglacial, slope, aeolian, hydrological, volcanic, tectonic etc.) and a huge variation in landform and landscape character. The conclusion must be that there is as much geodiversity in the world as biodiversity. In fact, no other known body in the solar system approaches the geodiversity of the Earth, and it is probable that the major factors explaining this geodiversity are:

- Plate tectonics – absent on all other planets in our solar system, with the possible exception of early episodes of plate tectonics on Mars,
- Climatic differentiation through space and time – with related diversity of physical processes, sediments and landforms; and
- Evolution – creating the diversity of the fossil record.

Given the influence that geodiversity has on biodiversity and its evolution, it is probably no coincidence that the most geodiverse known body in the solar system is also the one where complex life has developed (Ward and Brownlee 2000).

Figure 1. Speleothems in Carlsbad Caverns National Park, New Mexico, USA.

VALUES AND THREATS

Over 30 values of geodiversity have been identified (Gray 2004) based on:

- Intrinsic value (free of human valuation);
- Cultural values (e.g. Uluru (Ayers Rock, Australia), Petra, Stonehenge, White Cliffs of Dover);
- Aesthetic values (e.g. Grand Canyon, Canadian Rockies, Norwegian fiords);
- Economic values (e.g. oil, coal, construction geomaterials, metals, gemstones);
- Functional values (e.g. geodiversity creates biodiversity);
- Scientific/educational values (e.g. Joggins Fossil Cliffs, NS; Miguasha, QC).

In all these cases, it is the diversity of the geological resources/features that is important. These values can be referred to as 'geosystem services', the geological equivalent of the 'ecosystem services' that have been debated extensively by ecologists as demonstrating the value of biodiversity to human society.

There are, however, many threats to geodiversity. There is a natural tendency to think of wildlife as being fragile and vulnerable and therefore in need of conservation, whereas rocks and mountains are seen as stable, static and much too prolific ever to be endangered. This is an oversimplification because many geological sites, including delicate cave stalactites, are extremely fragile (Fig.1). In the Carlsbad Caverns in New Mexico, USA, thousands of cave deposits have been damaged by visitors over the years, often in seeking physical souvenirs of their visits. The same is true of petrified wood. At one site in Yellowstone National Park, whole fossil tree trunks have been removed by visitors. At Crackington Haven in Cornwall, UK, the beach comprises dark grey, rounded shale pebbles containing attractive quartz veins, significant amounts of which have been removed by both bucket and trailer-load for use in garden landscaping.

Other threats to geodiversity include the quarrying of important landform features, including eskers, limestone pavements and volcanic cones. In some instances, particularly where strip mining is involved, whole landscapes may be destroyed by quarrying operations, as in the case of the North Bohemian coal mining area in the Czech Republic and the Athabasca Tar Sand landscapes in Alberta. Other impacts on geodiversity include the destruction or burial of geosites by urban expansion and related infrastructure, interference with the operation of natural processes by engineering of river banks or coastlines, soil erosion resulting from unsustainable agricultural practices, and the remodelling of topography to create golf courses. But the biggest threat of all is probably ignorance of the potential impacts of human actions.

Since it has been demonstrated in this section that geodiversity is of value, but may also be threatened, it clearly follows that there is a need for conservation:

Value + Threat = Conservation Need

In the realm of ecology, it may be possible to nurture rare species in zoos, reintroduce species into the wild or establish seed or DNA banks. In some cases, restoration of physical systems is also possible; e.g. the restoration of channelized rivers or coastlines obscured by sea defences. But, once destroyed, important rock, mineral and fossil sites cannot be restored and this means that their conservation is even more important.

EVOLUTION OF THE GEODIVERSITY PARADIGM

During the 1990s, geodiversity as a conservation concept was developed in Tasmania (e.g. Kiernan 1996, 1997) and, crucially, was adopted in 1996 as a key principle in the Australian Natural Heritage Charter (Australian Heritage Commission 1996, updated 2002). This gave equal weight to biodiversity and geodiversity in assessing proposals for nature conservation sites. For example, Article 5 states that, *"conservation is based on respect for biodiversity and geodiversity. It* *should involve least possible physical intervention to ecological processes, evolutionary processes and earth processes"*.

In Europe, too, geodiversity started to have an impact from the start of the present century. An important international milestone was the publication by the Nordic countries (Sweden, Norway, Finland, Denmark and Iceland) of '*Geodiversitet i Nordisk Naturvard*' (Johansson 2000). This made the case for conservation of the superb geodiversity of these countries, and an English summary (Nordic Council of Ministers 2003) has helped to make the case more internationally accessible. In the UK, the term is now widely used within the nature conservation agencies (e.g. Stace and Larwood 2006; Webber et al. 2006; Scottish Natural Heritage 2007), in the minerals industry (e.g. English Nature 2003) and in government planning guidance (e.g. Department of Communities and Local Government (DCLG) 2005, 2006), and is starting to be used in regional and local government planning documents. In addition, about 40 Local Geodiversity Action Plans are already published or are in preparation (e.g. Lawrence et al. 2007), a Company Geodiversity Action Plan for the aggregates industry has been published (Thompson et al. 2006), and a National Geodiversity Action Plan is in preparation. The term has also been used in several other countries including Spain (e.g. Nieto 2001; Serrano and Ruiz-Flaño 2007), Portugal (e.g. Brilha 2005; Azevedo 2006), Italy (De Waele and Grafitti 2004; Piacente and Coratza 2005), Poland (e.g. Kozlowski 2004), Ireland (Moles and Moles 2004), Japan (Watanabe 2005) and the USA (Santucci 2005).

As a result of this international acceptance and usage in policy and practice, it has been argued (Gray 2008) that, *"geodiversity now has the theoretical/conceptual status and the history of usage that means that it meets various dictionary definitions of a 'paradigm'"*. These definitions include 'a theoretical framework of ideas', 'a generally accepted model of how ideas relate to one another, forming a conceptual framework within which scientific research is carried out', and 'a set of assumptions, concepts, values and practices that constitutes a way of viewing reality for a community that shares them, especially in an intellectual discipline'. In this writer's view, under any of these definitions, 'geodiversity' unquestionably has attained the status of a significant geological paradigm.

GEODIVERSITY AS THE BASIS FOR GEOCONSERVATION

Although the word, geodiversity, was first used only in the 1990s, the principles behind its application to nature conservation have a longer history. For example, in the UK, the Report of the Wild Life Conservation Special Committee (Huxley 1947) that led two years later to the establishment of the Nature Conservancy and Sites of Special Scientific Interest (SSSI), contains the following quote:

> *"Great Britain presents in a small area an extremely wide range of geological phenomena…the supply of a steady flow of trained geologists for industrial work at home and overseas, requires that there shall be available in this country a sufficient number of representative areas for geological study"*
>
> (Huxley 1947, para 64)

For 'range of geological phenomena' in this quote, geodiversity would easily substitute, and 'representative areas' must logically mean areas representative of the country's geodiversity.

Similarly, the Geological Conservation Review (GCR), which undertook a major site selection program in Britain between 1977 and 1990, was intended to *"reflect the range and diversity of Great Britain's Earth heritage"* (Ellis et al. 1996, p. 45). Site selection was based on three main criteria, one of which was, *"sites that are nationally important because they are representative of an Earth Science feature, event or process which is fundamental to Britain's Earth history"* (Ellis et al. 1996, p. 45). Note the use of the words 'range', 'diversity' and 'representative' in this quote.

Similar uses of geodiversity principles in nature conservation site selection can be found in other countries. For example, the USA has two main conservation programs. The National Parks network is world famous and new units can be added if they meet certain criteria, one of which is that *they must not represent a feature already adequately represented in the system*. Similarly, to be included on the National Natural Landmarks list, *units must be one of the best examples of a type of biotic community or geologic feature*. In other words, in the USA there is an attempt to conserve different types of geologic features, i.e. geodiversity.

Ireland has come late to geoconservation but is now selecting sites. The Irish Geological Heritage program has identified 16 geological themes, e.g. Precambrian, coastal geomorphology, etc. *"Each theme is intended to provide a national network of Natural Heritage Area sites and will include all components of the theme's scientific interest"* (Parkes and Morris 2001, p. 82), i.e. the system is intended to establish a representative selection of Ireland's geodiversity.

In Canada, the National Parks system is designed to protect representative examples of Canada's 39 natural areas; these have been defined on the basis of both topography and ecology, and the Canadian National Park system is partly intended to reflect the topographic geodiversity of the country, although the main aim is to preserve 'ecological integrity'. The network of parks is still being developed to include at least one National Park in each of the 39 natural areas

Until recently, World Heritage Sites (WHS) have been proposed by countries and accepted by UNESCO if they met the criterion of universal heritage value, i.e. UNESCO adopted a reactive role. In the last few years, the International Union for Conservation of Nature (IUCN) and UNESCO have become more proactive, and this includes the geological component of the WHS list. For example, Dingwall et al. (2005) have examined the list to determine if the geological timescale is fully represented. They discovered a significant gap at the Silurian as no sites, of this age, are represented. They have also proposed establishing a list of 13 geothemes to help in assessing future WHS applications and in identifying possible gaps in representation (Table 1). There is a sense here of trying to ensure that the world's geodiversity is represented in the WHS list. However, at present it is rather an inadequate representation, and in particular, with only two stratigraphic sites listed, it is evident that most Global Stratotypes have no *international* protec-

Table 1. Proposed geothemes for geological World Heritage sites and number of current sites within each theme (after Dingwall et al. 2005). Some sites fall into more than one theme.

Geotheme	No. of World Heritage Sites
Tectonic and Structural Features	3
Volcanoes/Volcanic Features	13
Mountain Systems	11
Stratigraphic Sites	2
Fossil Sites	11
Fluvial/Lacustrine Systems/Landscapes	10
Caves and Karst	7
Coastal Development	8
Reefs, Atolls and Oceanic Islands	1
Glaciers and Ice Caps	6
Ice Ages	7
Arid and Semi-arid Landforms and Landscapes	4
Meteorite Impact	1

tion. This ought to be a major concern for the geological community.

From this brief review, it should be clear that several countries have been, or are, using geodiversity as a guiding principle in the selection of conservation sites, even if they have not used this term. UNESCO is increasingly interested in using this principle in assessing proposed sites to add to the World Heritage list.

GEOCONSERVATION MANAGEMENT OBJECTIVES

It is widely accepted that geoconservation sites must be managed in different ways depending on the type of site. For example, Natural England [www.naturalengland.org.uk/conservation/geology] recognizes three types of geoconservation sites:

- *Exposure Sites* are those where the geological feature extends underground, so that the principle management objective is to maintain exposure of the strata, whether by quarrying, periodic clearing and cleaning, or by coastal or fluvial erosion.
- *Finite Sites* occur where geological features are of limited extent, so that any removal may cause depletion of the resource. Geosite management generally controls the removal of material.
- *Integrity Sites* are geomorphological sites where the dynamics of active processes or the integrity of landform contouring need to be retained.

These ideas can be further refined by identifying geoconservation management objectives for different elements of geodiversity (Table 2). It is clear from this that geoconservation management is complex, requiring acknowledgement of the very different objectives that must be applied. For instance, the conservation of rare fossils must involve strategies very different from those concerned with conservation of soils, which in turn are very different from those required for the conservation of natural physical processes.

GEOCONSERVATION METHODS

What holds for geoconservation management objectives, also holds for geoconservation methods, a classification of which is suggested below in this section. Some methods can be applied to all elements of geodiversity, but others are much more specialized. In many cases, several methods are applied at the same site/area. An outline of the available methods, with some examples, is given below.

Secrecy

This method is used principally at fossil and mineral sites, where discovery is not immediately advertised until research work is completed and, even then, the whereabouts of the site may not be made public. Examples that apply to bedrock exposures are some rare Ediacaran fossil sites in South Australia that are not publicly advertised.

Physical Restraint

This is an important method that is intended to prevent public access to very sensitive geological sites, particularly fossil, cave and active process sites; the permeability of the restraint may vary. In the case of caves containing fragile speleothems, the entrances can be gated and locked, thus preventing public access and providing a very impermeable restraint. An example is the entrance to Shooting Star Cave in Tasmania, where a locked metal grid prevents access to all except *bona fide* cave researchers. In some cases, visitor centres/museums are constructed over important geosites, thus restricting access to opening times when the sites are supervised. An example is the Fossil Quarry site at Dinosaur National Monument in Utah, USA, where the quarry exposure is covered by a visitor centre/research facility, although this serves also to protect the site from the effects of weathering. Similarly, several fossils in Dinosaur Provincial Park, Alberta, are covered by small buildings to prevent loss or damage. Slightly less secure are sites that are surrounded by high fencing. Examples here include the petrified tree near Mammoth in Yellowstone National Park and the fossiliferous Silurian ripple beds at Wren's Nest National Nature Reserve in England. More permeable physical restraints may involve lower fencing or simply a surfaced path displaying notices requesting visitors not to leave the path, e.g. at Craters of the Moon National Monument in Idaho, USA. In the case of physical processes, fencing is often used for health and safety reasons, i.e. to avoid injury to visitors, as well to prevent disturbance of the operation of natural processes. Examples occur at several hot spring sites in Yellowstone National Park and in Iceland. Boardwalks are often used in coastal sand dune locations to prevent pedestrian impacts on the fragile dune systems.

Reburial

This is a rather specialized and rare method of geoconservation that can be applied to fossil sites in particular, in order to prevent access by covering sites with soil following exposure. This method allows future study of fossils

Table 2. Proposed management aims for different elements of geodiversity (after Gray 2008).

Element of Geodiversity	Rare or Common	Management aims
Rocks & Minerals	Rare	Maintain integrity of outcrop and subcrop. Remove samples for curation.
	Common	Maintain exposure and encourage responsible collecting. Encourage sustainable use. Value historic and modern uses of geomaterials.
Fossils	Rare	Wherever possible, preserve in situ. Otherwise remove for curation.
	Common	Encourage responsible collecting and curation.
Landform		Maintain integrity of landform(s). Encourage authentic contouring in restoration work and new landscaping schemes.
Landscape		Maintain contribution of natural landform, rock outcrops and active processes to landscape. Encourage authentic design in restoration work and new landscaping schemes.
Processes		Maintain dynamics and integrity of operation. Encourage restoration of process and form using authentic design principles.
Soil		Maintain soil quality, quantity and function.

in situ. An example occurs in Sheffield, England where Boon (2004) described some Westphalian fossil tree stumps, originally contained within wooden sheds to protect them from the elements and souvenir hunters, but recently reburied by soil.

Excavation/Curation

This is a commonly accepted method of geoconservation, particularly for vulnerable fossils and minerals which are carefully removed to a museum laboratory, cleaned and stored or displayed. Examples include the Royal Tyrrell Museum at Drumheller, Alberta, the Smithsonian Natural History Museum in Washington, DC, and the Miguasha Visitor Centre in Québec.

Permitting/Licensing

This is used at some sites to control access by visitors and research workers. A famous example is access to 'The Wave', a series of smooth water-cut channels through the red and white, crossbedded aeolian dunes of the Jurassic Navajo Sandstone (Fig. 2) midway between Page and Kanab on the Utah–Arizona border. Access here is restricted by the Bureau of Land Management, which issues permits to a maximum of 20 visitors per day. Many protected fossil sites restrict collecting and research by issuing licenses. An example is the Walcott quarry (Burgess Shale) site in Yoho National Park, Golden, BC, where access is only allowed under license or with a trained guide.

Supervision

This is rarely used in geology because of cost, but a number of examples can be given of different supervision strategies:

- ***Static Rangers.*** Occasionally, rangers in the US National Parks are positioned at important sites to guard against deliberate damage. This is the case, for example, at Mesa Verde National Park in Colorado, where archeological remains in cliff alcoves are protected in this way.
- ***Mobile Rangers.*** These are more common and rely on occasional ranger patrols of park trails or roads by foot or vehicle to try to observe misdemeanours by park visitors.
- ***Ranger-led Tours.*** These are important for visitor education and can be used to ensure that visitors touring a site are supervised throughout. Examples include some tours through sensitive caves at Carlsbad Caverns National Park, New Mexico, USA, where rangers at both front and rear of tour parties can supervise group behaviour.
- ***Exit Searches.*** At Petrified Forest National Park, Arizona, USA, visitors' cars may be searched on the exit roads from the park to try to ensure that large quantities of fossil wood are not removed from within the park boundaries.
- ***Public Surveillance.*** Where sites lie close to residential areas, local residents, aware of the importance of nearby geological sites, may voluntarily supervise the access points. An example occurs at Valentia Island, Ireland, where access to a dinosaur trackway on the island is monitored by residents (Parkes 2001).
- ***Remote Surveillance.*** In some cases, cameras are installed to monitor visitors to sites. An example is the Stump Cross Caves in the Yorkshire Dales National Park, England, where a number of CCTV cameras oversee key speleothem locations (also protected by metal grills).

Benevolent Ownership

This applies to sites and areas that are owned by organizations or individuals with a clear commitment to geoconservation. Therefore, it is likely that all elements of geodiversity within the owned land will be managed in a way that protects the geoheritage interests. Federal or provincial governments own and manage many protected areas, but other organizations also play a role. An example is the National Trust in England, which owns over 1000 km of coastline and which has recently published a geological policy (National Trust 2007). The Museum of the Rockies in Montana, USA now owns

Figure 2. 'The Wave', water-eroded channels in the dune-bedded Jurassic Navajo Sandstone near the Utah–Arizona state border, USA. Access is restricted to a maximum of 20 visitors per day. Even so, they can get in each other's way!

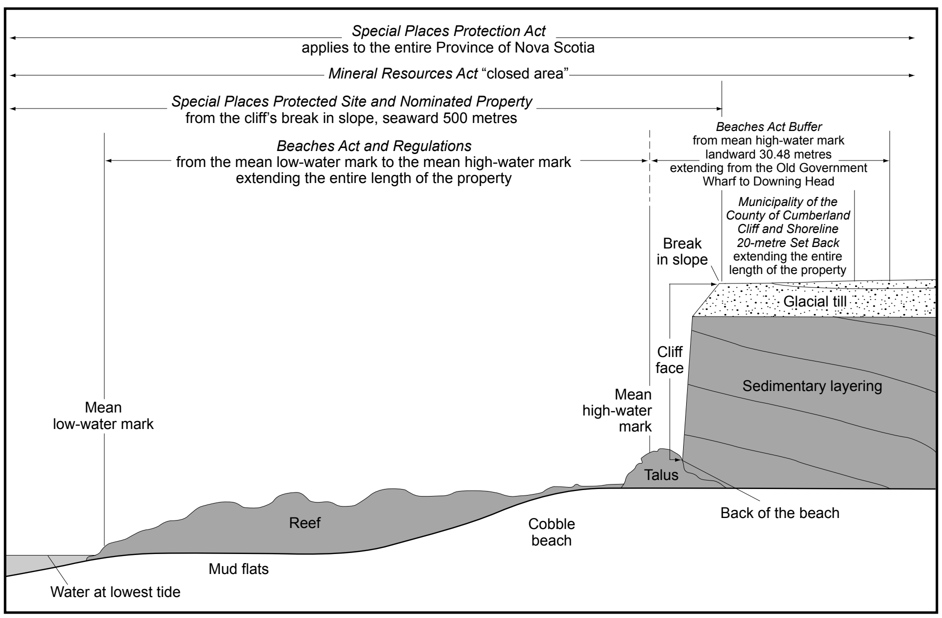

Figure 3. A diagram illustrating the Joggins Fossil Cliffs World Heritage Site, Nova Scotia, Canada, and the legislation that protects the site and its surroundings (after Joggins Fossil Institute 2007).

Egg Mountain, noted for the discovery of Maiasaur fossils (Horner and Dobbs 1997).

Legislation

Legislation is widely used to give formal protection to specific areas, including geological and geomorphological sites. The authorization to establish Canada's National Parks was given by the *National Parks Act* and revised by the *Canada National Parks Act* (2000). Several pieces of provincial legislation support the formal designation of various types of provincial protected areas, e.g. Alberta's *Provincial Parks Act* (1980) and *Wilderness Areas, Ecological Reserves and Natural Areas Act* (1989). But sometimes suitable categories for designating geological sites are unavailable. For example, the global stratotype of the Precambrian–Cambrian boundary at Mistaken Point in Newfoundland has had to be designated as an Ecological Reserve! It should be noted that not all designations are supported by legislation; e.g. inscription on the World Heritage List or recognition as a Global Geopark do not by themselves provide any protection. This has to be achieved by national or provincial legislation and/or by management policies. For example, various parts of the recently inscribed (2008) World Heritage Site at Joggins in Nova Scotia are protected by *the Special Places Protection Act* (1989), the *Beaches Act* (1989), the *Mineral Resources Act* (1990), and the *Municipality of the County of Cumberland Secondary Planning Strategy* and *Land Use Bylaw for the Joggins Planning Area* (2006) through *the Municipal Government Act* (1998) (see Fig. 3).

Policy

Policy is defined here as non-legislative measures, and can be used to achieve geoconservation objectives in many ways. It applies to all elements of geodiversity and to both formally protected sites and the wider landscape (see page 57); in some cases, legislation enables the policy details to be developed later. For example, although the *Nature Conservation (Scotland) Act* (2004), drafted by Scottish Natural Heritage, requires a *Scottish Fossil Code* to be prepared and published, it does not specify the policy content of the code. All Canadian National Parks are required to have a management plan, but again the details are left to policy development processes and consultation. Most of these plans include policies for geology and landforms. For example, the Jasper National Park Management Plan (2000) has a policy to, *"protect and present significant geological, physiographic and soil features, such as the Maligne karst system, the Columbia Icefield (glacial geomorphology), the Jasper Lake dunes, alpine and sub-alpine permafrost, and fossils"*. An example of more detailed geoconservation policies is the 'Climbing Management Plan' at the Devil's Tower National Monument in Wyoming, USA, which aims to monitor and reduce the impact of climbing activities.

Education
Education also applies to all elements of geodiversity, and is especially relevant because it has been argued that the greatest threat to geodiversity is ignorance (Gray 2004). Education on geodiversity issues can be significantly advanced by expanding offerings of earth science topics in school and university curricula. Also needed are training courses for local government and planning officers, politicians, nature conservation and ranger staff and other professionals involved in decision-making on land and nature planning matters. Geodiversity education can also be expanded via television, magazine and newspaper articles; websites, museums, visitor centres, theme parks and geoparks, site-interpretation panels, visitor activities such as fossil and mineral collecting, geological trails with accompanying leaflets, and special events such as geology weeks (Gray 2004).

Most of these approaches, and others, are applied throughout Canada, but there are still important elements of geodiversity that remain unprotected. One example is the famous Cow Head conglomerate in western Newfoundland, whose most outstanding outcrops, containing many boulders larger than 1 m in diameter, occur along the western shore of the Cow Head peninsula (Fig. 4). Because this area lies just outside the boundary of Gros Morne National Park, it remains unprotected, presenting a compelling case for extending the boundary of the National Park to include this shoreline.

Figure 4. The Cow Head conglomerate, Cow Head, NL, Canada.

GEODIVERSITY IN THE WIDER LANDSCAPE
While some of the methods included in Table 2 apply to site conservation, others are more appropriate to the 'wider landscape'. Within nature conservation circles, there has been a growing dissatisfaction with an approach that relies solely on protected areas/sites to conserve nature. For example, Myers (2002, p. 54) argued that *"setting aside a park in the overcrowded world of the early twenty-first century is like building a sandcastle on the seashore at a time when the tide is coming in deeper, stronger and faster than ever"*. In other words, protected areas are becoming isolated from each other and vulnerable to human impacts, whereas a less fragmented approach to nature conservation is needed.

What has become known as the 'wider landscape' or 'protecting beyond the protected' approach began in relation to protecting fauna, which is dynamic and cannot identify when it is leaving the protection of a designated area. This led to the emergence of the idea of 'wildlife corridors' or 'greenways' linking protected areas, and allowing wildlife to move from one protected area to the next. In some countries, whole ecological networks of protected areas linked by these corridors were created, at least on paper (Jongman and Pungetti 2004). The Frontenac Axis Biosphere Reserve in Canada offers another example of the successful application of this approach, where geological considerations have been taken into consideration [http://www.pc.gc.ca/pn-np/on/lawren/natcul/natcul5_E.asp].

The concept of biodiversity has extended nature conservation philosophy to the whole landscape, including urban areas, identifying the need to protect habitats and species wherever they occur. It is clear that the same thinking can be applied to abiotic nature, because rocks, landforms, processes, soils etc. occur everywhere and are vulnerable to many threats (Gray 2004). In the same way that fauna move away from protected areas, so geomorphological processes are dynamic and difficult to conserve by the protected area approach. For example, protection of an underground cave system or a lake is problematic if the rivers flowing into them are polluted. The whole river catchment area needs to be managed sustainably in order to protect the cave system or lake in the long term. Similarly, natural coastal processes often operate on a large-scale, and interference with one part of a coastal cell may produce undesirable consequences for other parts of the coastline.

One of the objectives of geoconservation should be to retain the existing physical character of the landscape, including the natural topography, soils and uninhibited operation of natural processes. Where change is justified, it should be done with an understanding of the significance of the changes and with design conditions appropriate for achieving compatibility with the character of the local landscape. Restoration of land and processes to a more natural state should also be promoted. Geoconservation of this type is best achieved through policies for landscape management, through land-use planning systems and through effective partnerships.

CONCLUSIONS
Planet Earth is far more geologically

diverse than any other known body in the solar system. This is due mainly to plate tectonics, the Earth's climatic system and a variety of related processes responsible for the sedimentary record, landforms, and an impressively diverse fossil record of the evolution of life. Geologists have spent many decades describing and seeking explanations for the formation of rocks, minerals and landforms of the planet, but have spent relatively little time celebrating its geodiversity. Yet, by looking at the world in terms of its geodiversity, an enriched appreciation of our natural environment is gained.

The world's geodiversity is of value in several respects but is threatened by many human activities (Gray 2004). There is, therefore, a need for geoconservation, but the objectives and methods of geoconservation need to take account of the different elements of geodiversity. For example, the conservation of soils needs to be approached very differently from the conservation of fossils. Important geological sites can be protected by legislation, but soils and landscapes in the wider countryside are better conserved by policy development and partnerships.

Too many nature conservation bodies and policies are biocentric in outlook, and geoscientists need to promote equality of treatment for bio- and geodiversity as put forth in the Australian Natural Heritage Charter (1996, 2002), which states that "conservation is based on respect for biodiversity and geodiversity".

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