

## Valuing Geodiversity and Geoconservation: Developing a More Strategic Ecosystem Approach

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**ABSTRACT** This paper reviews the values and benefits of geodiversity and geoconservation in the context of Scotland's National Performance Framework and Strategic Objectives, particularly in relation to: economic development; climate change adaptation; biodiversity; science and education; and recreation, health and cultural inspiration. A key challenge is to improve the integration of geodiversity in environmental policy and in its implementation in order to deliver more holistic and sustainable environmental management and wider public benefits. This requires greater awareness and recognition of the key benefits and ecosystem services that geodiversity provides for society. With an overall objective of promoting integration of geodiversity into relevant policies and decision frameworks, we propose a more strategic, ecosystem-based approach to address: the future-proofing of ecosystem services, particularly in a context of climate change and rising sea-levels; conservation and sustainable management of geodiversity both in designated sites and in the wider countryside; raising awareness of the value of geodiversity and its contribution to ecosystem services; and improving understanding of geodiversity and key knowledge gaps. Such an approach is adopted in the Scotland's Geodiversity Charter.

**KEY WORDS:** Geodiversity, ecosystem approach, ecosystem services, strategic framework

*What happens to us  
Is irrelevant to the world's geology  
But what happens to the world's geology  
Is not irrelevant to us.*

Hugh MacDiarmid, *On a Raised Beach*, 1933

### 1. Introduction

For its size, Scotland has a remarkable geodiversity, both on land and beneath Scottish territorial and offshore waters, reflecting a rich and varied geological history that spans some 3 billion years of the Earth's existence. This has stimulated the development of many of the fundamental principles that underlie geoscience today (Trewin, 2002; Gordon & Barron, 2011). From a more applied viewpoint, Scotland's geodiversity has played, and continues to play, a critical role in national development, from providing coal, oil-shale and iron ore resources to power 19<sup>th</sup> century industrialisation, to underpinning the development of new

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technologies such as ‘carbon capture and storage’. Geodiversity has thus contributed greatly to Scotland’s financial wealth (Pye & Brown, 2002; Rippon, 2002). Similarly, offshore, there are clear links between marine geodiversity and ecosystem support, healthy diverse seas and economic development (oil, gas and renewables) (Baxter *et al.*, 2011). As presciently anticipated by Hugh MacDiarmid writing in the 1930s, geodiversity has much wider relevance in a number of key policy areas and forms the foundation of ecosystem services through its influence on landscape, habitats and species, economic activities, climate change adaptation, sustainable management of the land, river catchments and the coast, historical and cultural heritage, and people’s health and well-being (Gordon & Leys, 2001; Gray, 2004; Stanley, 2004; Stace & Larwood, 2006; Gordon & Barron, 2011). Many of these issues are being brought together under the UK Geodiversity Action Plan (UKGAP)<sup>1</sup> and in advocacy for a more holistic approach that recognises the wider benefits of geodiversity to society and integrates geodiversity more closely in environmental policy (Prosser *et al.*, 2011; Gordon *et al.*, 2012).

At an international level, there is also growing awareness of the importance of the conservation of geodiversity<sup>2</sup> and its wider values by the Council of Europe, the Nordic Council of Ministers, IUCN and UNESCO. The European Manifesto on Earth Heritage and Geodiversity (2004), advocates that unique Earth heritage sites and landscapes should be given protected status, and that sustainable development and restoration should respect and reflect geology, geomorphology and soils. In adopting Recommendation Rec(2004), the Committee of Ministers of the Council of Europe (2004) recognised the wider value of geodiversity: “geological heritage constitutes a natural heritage of scientific, cultural, aesthetic, landscape, economic and intrinsic values, which needs to be preserved and handed down to future generations”. Noting “the important role of geological and geomorphological conservation in maintaining the character of many European landscapes”, the Committee also recommended that geological and geomorphological features are essential characteristics of landscapes that need to be considered when applying the European Landscape Convention (2002). Resolution 4.040 on ‘Conservation of geodiversity and geological heritage’, approved by the IUCN General Assembly (IUCN, 2008) at the 4th World Conservation Congress in Barcelona, provides a benchmark statement of the wider role and relevance of geodiversity. It acknowledges, *inter alia*:

- that geodiversity is an important natural factor underpinning biological, cultural and landscape diversity, as well as an important parameter to be considered in the assessment and management of natural areas;
- that geological heritage constitutes a natural heritage of scientific, cultural, aesthetic, landscape, economic and/or intrinsic values, which needs to be preserved and handed down to future generations;
- the escalating impact of development, that is frequently unsustainable, upon the world’s geodiversity and geological heritage;
- that in planning such development, the intrinsic values, both material and intangible, of the geodiversity, geoheritage and geological processes present at natural areas are often underestimated or even ignored;
- that the conservation of geodiversity and geological heritage contributes to dealing with species loss and ecosystem integrity;
- the important role of geological and geomorphological conservation in maintaining the character of many landscapes.

Through the Global Geoparks Network, UNESCO has promoted the cultural and economic importance of geodiversity as a means to deliver geoconservation as part of a wider strategy for regional sustainable socio-economic and cultural development that safeguards the environment (Eder & Patzak, 2004). In Scandinavia, the Nordic Council of Ministers has supported collaborative geodiversity activities, including a report on *Geodiversity in Nordic Nature Management* (Johansson, 2000), that highlights geodiversity's wider values. In the Australian Natural Heritage Charter (Australian Heritage Commission, 2002), geodiversity is accorded equal status to biodiversity. There is therefore increasing acknowledgement, both in the UK and farther afield, that geodiversity has a vital relevance to society and that it impacts on many sectors in economic development and historical and cultural heritage through its contribution to ecosystem services. Crucially, the impacts on society and the costs of not understanding geodiversity have tended to be overlooked, with mismanagement resulting in soil erosion, landslides, enhanced impacts of flooding, coastal erosion and unsustainable use of resources. Although this is improving to some extent through natural flood management, catchment planning and integrated coastal zone management in many parts of the world, understanding of earth surface processes still needs to be integrated more comprehensively in policy, planning and decision frameworks (e.g. flooding in Thailand in 2011 had global economic implications due to unsuitable development on floodplains and lack of understanding of geomorphology<sup>3</sup>).

Nevertheless, geodiversity still lags significantly behind biodiversity in its recognition and integration in the wider policy environment, both in Scotland and more widely in the UK. In particular, there is a lack of a clear policy statement and national framework for geodiversity in Scotland, analogous to the Scottish Biodiversity Strategy, the Scottish Soil Framework or Scotland's Landscape Charter. The purpose of this paper is ~~to~~ not to produce such a policy or strategy, but rather to outline the evidence base and supporting context. In particular, the aims are to: 1) review the wider values and benefits of geodiversity in the context of key environmental policy drivers, using an ecosystem services approach; 2) indicate how geodiversity supports wider policies and Scotland's National Performance Framework; and 3) identify the key areas that should be addressed as part of a more strategic approach to the conservation and management of geodiversity.

## 2. The Values and Benefits of Geodiversity

An ecosystem approach, as defined under the Convention on Biological Diversity<sup>4</sup> seeks to achieve a more holistic way of looking after the natural environment and delivering more sustainable development. It recognizes that ecosystems are a form of public good, providing benefits and services that have value to people. The adoption of an ecosystem approach is now a key conservation policy driver, reflected in the Millennium Ecosystem Assessment (MA) (2005), the EU Biodiversity Strategy (European Commission, 2011), the UK National Ecosystem Assessment (2011) and the revised Scottish Biodiversity Strategy. Ecosystem services are typically grouped into four main categories as set out in the MA framework: provisioning, regulating and cultural services that directly affect people, and supporting services needed to maintain the other services. The significant role of geodiversity in contributing to ecosystem services is reviewed elsewhere (Gordon & Barron, 2011; Gray, 2011, this volume). Here, we highlight 5 key areas that relate to Scotland's Strategic Objectives (Table 1): economic development; climate change adaptation; biodiversity; science and education; and recreation, health and cultural inspiration.

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## 2.1 Economic development

In Scotland, as in most countries, economic and industrial development during recent centuries has been founded on its geological resources. Today, these are fundamental to economic development and essential to maintaining our modern economy and lifestyle. A local supply of construction aggregates is vital for the building and maintenance of our infrastructure. Energy minerals including coal are used to generate a constant supply of electricity. In the UK, each person uses an average of over 10 tonnes of minerals and metals annually (British Geological Survey, 2008). Mineral resources are finite and they can only be worked where they occur. It is therefore essential that we use minerals in the most efficient and sustainable manner.

Scotland is fortunate to host significant useful mineral resources, which provide for local, regional, national and international needs. Resources include coal, igneous rock (for road surfacing), sand and gravel, limestone, sandstone, silica sand (mainly used for making glass containers), brick clay and peat (Hannis & Bee, 2008; Bide *et al.*, 2011). Half of Great Britain's igneous rock comes from Scottish quarries, many of which produce important high specification aggregates. 33% of the coal extracted in Britain comes from Scotland: nearly half of that from the surface mining sites in East Ayrshire (Bide *et al.*, 2011). In 2009, the total value of minerals produced in Scotland (excluding oil and gas) was approximately £610 million. This represents 26% of the value of land-won minerals produced in the whole of the UK (Bide *et al.*, 2011). The economy gains not only from the value of the indigenous mineral production itself, but also from the much greater value of the downstream industries that consume these raw materials, such as construction, energy production and chemicals manufacture, key sectors of both the Scottish and British economies. The construction industry is heavily dependent on locally-sourced raw materials to reduce transport costs and maintain competitiveness. Construction aggregates represent half the value of all minerals produced in Scotland. Employment is also an economic indicator of the importance of minerals. Onshore mineral extraction (excluding coal) in Scotland provides around 1500 direct and over 4000 indirect jobs (Department for Communities and Local Government, 2011), many of which are in rural areas. Offshore, Oil and Gas UK estimate the workforce employed on the UK Continental Shelf at 350,000 (Bide *et al.*, 2011).

Geodiversity also provides crucial resources for energy generation. Coal accounts for around 40.28% of local and national Scotland's electricity generation (Department for Energy and Climate Change, 2012). Oil and gas, too, have contributed significantly to the UK economy since the 1970s; in 2009, UK-produced oil and gas was valued at £24.8Bn (at 2006 prices) (Bide *et al.*, 2011). Onshore, UK-produced coal was valued at £906M (at 2006 prices) in 2009, with 35% of this produced in Scotland (Bide *et al.*, 2011). During the post-war expansion of hydro-electric power in Scotland, many glens were dammed to provide a head of water to drive generating stations. More recently, the development of renewables has become one of the Scottish Government's highest priorities, with a target of generating the equivalent of 100% of electricity in Scotland from renewable sources by 2020. Onshore wind farms depend on suitable topographic locations, while the coastal and submarine topography facilitate development of tidal schemes and offshore wind farms. The tidal rapids within the Pentland Firth alone are expected to generate 1.2GW through wave and tidal devices. Many opportunities also exist for small-scale run-of-river hydro-electric schemes due to the nature of the terrain (elevation drop) and natural flow. providing that appropriate protection for the water environment and fisheries can be secured (SEPA, 2010; Robson *et al.*, 2011).

Most of Scotland's famous landscapes and scenery are founded on geodiversity. Visitors to Scotland rank scenery as the main attraction of Scotland as a tourist destination, ahead of

**Comment [MSOffice1]:** For non-geologists, an explanation of the uses of igneous rock and silica sand would be useful

**Comment [MSOffice2]:** Much igneous rock is used close to source.

**Comment [MSOffice3]:** What has been the effect of in-quarry processing? I know Trearne is now back in the supply of agricultural lime with an in quarry plant.

**Comment [MSOffice4]:** In Scotland or the UK?

**Comment [MSOffice5]:** Worth noting that most effective onshore windfarm is on Shetland. However, the remote location of many renewables sites is committing Scotland to a long-distance power transmission grid. This is not an easy system to incorporate local power generation into.

**Comment [MSOffice6]:** I know Penicuik Development Trust is investigating this. RoR schemes have been popular in the US and are often community-owned. Are there conflicts with salmonid fishing?

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history and culture (VisitScotland & Scottish Natural Heritage, 2002). The country's economy benefits by £17.2 billion a year from sustainable use of the natural environment (RPA & Cambridge Econometrics, 2008). The environment also supports 242,000 jobs, or 14% of all full-time jobs in Scotland (RPA & Cambridge Econometrics, 2008). However, the Scottish environment is much more than an asset for tourism-based activities. It provides an attractive environment in which to live and do business. For example, 20% of our industries depend to a large extent on the environment, including not only tourism, agriculture, fishing and forestry, but also food and drink production, water supplies, renewable energy, timber processing and recreation (RPA & Cambridge Econometrics, 2008). Geodiversity is clearly a contributing factor in all these areas.

Geotourism is growing in importance, both globally and in Scotland, as reflected in the expansion of numbers of European and Global Geoparks<sup>5</sup> and in the development of visitor attractions and products (McKeever *et al.*, 2006; Dowling & Newsome, 2010; Newsome & Dowling, 2010). Geoparks provide a framework that supports sustainable economic development particularly in remote areas, geoconservation and opportunities for local communities to use the resource of their landscapes and their geological stories in creative ways for the development of geotourism-based activities and niche branding of local products and services (Eder & Patzak, 2004; Hambrey Consulting, 2007; Morrison & MacPhail, 2009). In Scotland, there are opportunities to develop more holistic interpretation linking geodiversity, biodiversity, land use, environmental resources and cultural heritage, using national gateways both real (e.g. Our Dynamic Earth and the museums) and virtual (e.g. the scottishgeology.com website - <http://www.scottishgeology.com/>) linked to a network of regional hubs each with its own satellite sites (McKirdy *et al.*, 2001). Where appropriate, such interpretation should integrate with existing visitor facilities and the National Parks and Geoparks, adding quality and value to the visitor experience. However, there are still major challenges for Scotland's Geoparks to engage with the business community and to develop a secure, long-term, financial model. Integration with the tourism industry at a strategic level will also be crucial, as indicated by the success of the 'Landscapes from Stone' programme in Ireland (McKeever & Gallagher, 2001).

Comment [MSOffice7]: I think this site is under redevelopment

## 2.2 Living in a dynamic world: adapting to climate change

Understanding geodiversity, and particularly the responses of geomorphological processes, has a key part to play in adapting to climate change and sea-level rise. Changes in geomorphological processes are likely to have significant implications for most ecosystems. Some habitats may become more dynamic as a result of changes in the nature and rate of geomorphological processes. Enhanced or more variable rates of geomorphological activity may be too fast for not allow some habitats and species to adapt. Increased incidence of flooding, and consequent enhanced erosion and rates of sediment movement, will affect the quality of freshwater and brackish habitats. Similarly, any changes in seasonal flows (e.g. in the timing and duration of droughts) will have implications for these habitats. Overall, there may also be less recovery time between extreme events, such as wash-out of spawning areas.

Comment [MSOffice8]: Having visited the English Riviera geopark in December (Torquay area Devon, I was struck at the support from the council (Unitary Authority) and Kent's Cavern (local business with strong geodiversity link). Their reasoning was that by targetting outdoors-orientated visitors, they could extend their tourist season. Contrast this with Scotland. Lochaber, which is pushing Fort William as the UK outdoors capital, has let the Geopark go. Strong similarities but different outcomes. Why? I would argue proximity and awareness of the Jurassic Coast in the case of Devon. In Lochaber, the sealochs and mountains seem to be treated as 'externalities'.

Climate change scenarios suggest that some landforming processes that are also hazardous (such as coastal flooding and erosion, flash floods and landslides) are likely to occur more frequently, and their effects may be exacerbated by the legacy of longer-term trends. For example, the postglacial uplift of Scotland is now being outpaced by global sea-level rise (Rennie & Hansom, 2011). If the observed recent patterns are maintained, this has significant implications for the natural heritage, strategic planning, flood risk management and

Comment [MSOffice9]: volatile or variable would better convey rapid switching in regimes.

sustainable development on Scotland's coast, and particularly on low-lying coastal zones and river mouths around the major cities. The response to hazards often results in expensive site-by-site geotechnical solutions (e.g. more coast protection). Many of these approaches are not sustainable, and may exacerbate or transfer the problem elsewhere in the catchment or along the coast, with consequent impacts on natural heritage interests (e.g. reduced sediment supply to maintain beaches, machair and saltmarshes). For dynamic landscapes (rivers, coasts and steep hillsides), sustainable adaptation measures require, where practicable, allowing space for natural processes to operate, and minimising interventions that work against natural processes (Prosser *et al.*, 2010). For example, landforms and habitats, such as beaches and salt marshes, act as natural forms of coast defence but require a sediment supply to maintain them and sufficient space to evolve (e.g. through managed realignment). To be effective, management decisions also need to be made at appropriate spatial scales (e.g. catchments and coastal zones). This is being recognized in the development of 'natural flood management', involving integrated catchment solutions and the restoration of the natural function of floodplains as flood buffers, with concomitant benefits for the natural heritage (e.g. under the Flood Risk Management (Scotland) Act 2009). The concepts of working with nature and making space for natural processes have broader value to society as a whole, not only in practical terms of managing flooding and coastal erosion, but also in terms of the economic costs of ignoring them. However, engagement of geoscientists with appropriate conservation agencies, land owners, communities and other stakeholders will be crucial (Prosser *et al.*, 2010; Lane *et al.*, 2011).

Comment [MSOffice10]: However, the buy-in from local farmers and residents to these schemes has been terrible on the Wash and in the Thames marshes.

### 2.3 Underpinning biodiversity

Geodiversity is the foundation of all terrestrial ecosystems, delivering many essential supporting services for biodiversity, including soil formation, biogeochemical (nutrient) cycling and water cycling, as well as provision of minerals, nutrients, landform mosaics and geomorphological processes (e.g. water flow regimes) for habitat creation and maintenance. Scotland's biodiversity depends on the continued operation of these services. Many habitats owe their origins to geological and geomorphological processes (e.g. coastal sand dune/machair systems, the estuaries and salt marshes which provide the wintering sites for internationally important goose populations, and limestone pavements). Management of sites for biodiversity therefore requires an understanding of their geological and geomorphological setting and current process dynamics, for example in the management of freshwater (Corenblit *et al.*, 2007; Vaughan *et al.*, 2009), coastal (Everard *et al.*, 2010; Jones *et al.*, 2011) and upland (Thompson *et al.*, 2001; Orr *et al.*, 2008) systems. In many cases, maintaining natural processes is a key part of conserving biodiversity. Consequently, it is increasingly recognised that conservation management of the non-living parts of the natural world is crucial for sustaining living species and habitats (Hopkins *et al.*, 2007; Beier & Brost, 2010; Anderson & Ferree, 2010). The value of a more integrated approach for sustaining natural capital is now acknowledged at a strategic level, for example in the Convention on Biological Diversity and the European Landscape Convention and in the growing emphasis on an 'ecosystem approach' in conservation management. At a more practical level, it is being implemented through Integrated Coastal Zone Management and Integrated Catchment Management/Sustainable Flood Management schemes.

From a natural heritage viewpoint, more integrated approaches to nature conservation and the management of sites and landscapes would help to strengthen and add value to the Scottish Biodiversity Strategy (Scottish Executive, 2004) by recognising: i) the value of geodiversity as an intrinsic constituent of the natural heritage alongside biodiversity and landscape

character; and ii) the role of geodiversity in supporting and regulating a wide range of environmental and ecological services essential for supporting habitats and species. In terms of management, it means conserving geodiversity and making space for natural processes as a form of insurance to help provide mosaics of environments (sites with the diverse geology, landforms, soils, drainage, water/sediment /nutrient flows) and options to enable habitats/species to be maintained, adapt, relocate or be restored and, where appropriate, supporting ecological networks and connectivity. Where practical, it also requires working with, rather than against, natural processes, in effect 'allowing space for nature' to enable coasts, floodplains and slopes to evolve with minimal human intervention, rather than attempting to 'fix and control'. This means accepting the inevitability of natural change as part of maintaining ecosystem functions, and in many cases attempting to maintain the status quo will not be an option (e.g. Pressey *et al.*, 2007). In addition, learning from the past through analysis of palaeoenvironmental archives and geomorphological records can provide long-term perspectives on trends, rates of change and future trajectories in ecosystems (Dearing *et al.*, 2010), which will help to inform adaptation, spatial analysis and scenario modelling of geomorphological risks to habitats, species and ecosystems, and assessment of how realistic biodiversity targets are, taking account of geodiversity factors and the magnitude and speed of their changes. Geodiversity-informed management strategies will therefore be a vital part of future-proofing biodiversity and ecosystems where that is practically possible, but their implementation will require close partnership working across the geoconservation and geoscience communities, as well as with other sectors of nature conservation, policy makers, planners and communities. It is vital that geologists and geomorphologists actively engage in wider networks and with those involved in conservation, ecosystem services and climate change adaptation work (e.g. through the Valuing Nature Network, the Living with Environmental Change programme and local initiatives) (Gray *et al.*, submitted).

**Comment [MSOffice11]:** But so few biodiversity and conservation organizations have people with this knowledge in their teams. SNH is not replacing staff in this area. Much baseline information could be supplied from desktop work but the need for 'boots on the ground' remains. Who will fill this role? Ecological consultants, geotechnical firms?

## 2.4 Science and education

Scotland's geodiversity has significant value as part of the geoheritage of Great Britain. The geological development of Scotland has given rise to an exceptional geodiversity, both on land and beneath Scottish territorial and offshore waters (Trewin, 2002; Gordon, 2010; Brooks *et al.*, 2011). Many sites in Scotland are of great importance to geoscience for their rocks, fossils and landforms, demonstrating geological processes or events of international significance. This intrinsic value is encapsulated in the inclusion of key features of geological and geomorphological interest in the national system of Sites of Special Scientific Interest, based on the Great Britain wide Geological Conservation Review (GCR) (Ellis, 2011). Scotland's geodiversity is consequently an asset of national and international importance for geoscience research and education.

**Comment [MSOffice12]:** on the basis of geological or geomorphological interest

Scotland's geology and geologists have also played a fundamental part in the development of the principal concepts in geoscience (including physical geography) (Gordon & Barron, 2011). In particular, they have provided crucial evidence for interpreting geological events and processes of global significance associated with recognition of the duration of geological time, plate movements, crustal deformation, volcanism and ice ages. For example, evidence for the closure of the Iapetus Ocean and the formation of the Caledonian mountains, volcanism, events associated with the opening of the North Atlantic Ocean, and glaciation have all been instrumental in achieving fundamental advances in geoscience. Similarly, Scotland's fossil heritage has had an influential role in the development of the standard units of time and in advancing our understanding of the evolution of the plant and animal kingdoms. In the marine environment, the seabed beneath Scottish territorial and offshore

waters includes remarkably well preserved landforms that have revealed patterns and processes of ice stream behaviour within the last British-Irish Ice Sheet (Bradwell *et al.*, 2008; Stoker *et al.*, 2009), large submarine mass movement features (submarine slides), a range of dynamic bedforms (including sand and gravel waves and gas seepage forms) and areas of carbonate production that underpin onshore features such as the dunes and machair of the Western Isles and Northern Isles of Orkney (Brooks *et al.*, 2011). Scotland's geodiversity is also significant in the context of our scientific and cultural heritage. The birth of modern geology took place in Scotland over 200 years ago through the discoveries of James Hutton, a leading figure in the Scottish Enlightenment, which laid the foundations of modern geoscience (McIntyre & McKirdy, 2012). There is thus a long-established tradition of world-class scholarship in geoscience in Scotland which continues to the present day, prompted not least by ~~ready access to~~ the extraordinary wealth of Scotland's geodiversity.

**Comment [MSOffice13]:** Access is a key issue. We have the SOAC and many sites in easy reach of the central Belt. But many good inland sites are now overgrown. Should there be a duty to maintain good

In its strategic framework for science in Scotland, *Science for Scotland*, the Scottish Government envisages science as key to delivering its Strategic Objectives and increasing sustainable economic growth (Scottish Government, 2008a). Geoscience is well-placed to meet these objectives in several high-level areas of particular relevance to society today<sup>6</sup>:

- understanding of Earth and environmental sensitivity from the records of the past to enable testing of trajectories, scenarios and adaptation for the future;
- development of holistic Earth models for climate change, incorporating processes and feedbacks in the atmosphere, oceans and cryosphere;
- resource security and waste management;
- hazards – understanding risk and uncertainty in the Earth (including those of tectonic and volcanic origin but also related to the consequences of climate change, including sea-level rise).

Addressing these issues requires not only fundamental research, but also high quality training for future generations of geoscientists. This extends more widely both to schools and wider public awareness of geoscience through lifelong learning opportunities. The Scottish Earth Science Education Forum (SESEF) has been instrumental in integrating geoscience and its wider relevance across a number of key areas of the Curriculum for Excellence. An essential component of such training and education is the availability of sites for field study, which links directly to the need for effective geoconservation.

### 2.5 Recreation, health and cultural inspiration

Scotland's geodiversity provides many opportunities for outdoor recreation, ranging from walking and cycling to rock climbing, caving, skiing, orienteering, canoeing, sailing, camping and outdoor adventure. In doing so, it contributes to people's physical and mental health and well-being and to the Scottish Government's strategy on health and the environment (Scottish Government, 2008b). Regular exercise in the form of walking is an excellent way to improve health and to explore geology and landscape (Stinton, 2009). There are many opportunities for walking on existing geotrails (e.g. British Geological Survey, 2004; Scottish Natural Heritage, 2004) and through visits to GCR sites, Local Geodiversity sites<sup>7</sup> and Geoparks<sup>8</sup>. There is also significant potential for integrating geology into existing long- and short-distance trails and adding value to the many walking festivals taking place annually in Scotland. Guided walks in Scotland's Geoparks and during Scottish Geology Festival events add to people's enjoyment of the outdoors. The extension of the International

**Comment [MSOffice14]:** BGS has also produced a few 'walkers guides' to geology and SNH Hostile Habitats book is a fantastic upland field guide that ranges from geology to human settlement



Appalachian Trail to Scotland<sup>9</sup> and other European countries will help to promote Scotland as a walking destination based on its geological heritage and landscapes. Use of new technologies such as iGeology (<http://www.bgs.ac.uk/igeology/>), mySoil (<http://www.bgs.ac.uk/mysoil/>) and interactive games (e.g. Rock Operator - [http://www.hoda.org.uk/hoda/Rock\\_operatoR.html](http://www.hoda.org.uk/hoda/Rock_operatoR.html)) will also enhance the visitor experience and the engagement of young people.

There are also new opportunities to integrate geodiversity within the Central Scotland Green Network (CSGN)<sup>10</sup> that forms part of the Scottish Government's Second National Planning Framework published in July 2009<sup>11</sup>. This is one of 14 National Developments considered to be essential elements of the strategy for Scotland's long-term development. The CSGN aims to build on the work of a number of existing regional and local initiatives to improve the environmental quality in an area stretching from Ayrshire and Inverclyde in the west to East Lothian and Fife in the east. This will make the post-industrial landscape a more attractive place in which to live, visit and do business. It reflects a growing recognition by Government, public agencies and local authorities of the contribution that high-quality greenspace can make to a range of outcomes - from supporting sustainable economic growth and improving quality of life, to protecting biodiversity and helping Scotland mitigate and adapt to climate change. Local Geodiversity Sites and activities undertaken by local geodiversity groups have an important part to play in this process. In addition, there are opportunities to promote BTCV (formerly British Trust for Conservation Volunteers) Green Gym volunteering both for people's fitness and improvement of geodiversity assets by site works such as path making and enhancement of GCR sites and Local Geodiversity Sites.

Landscapes and their geological features have also exerted a strong creative influence expressed through literature and poetry in Scotland, notably in the novels of Sir Walter Scott, Robert Louis Stevenson, Lewis Grassic Gibbon, George Mackay Brown, Neil Gunn and others and in the poetry of Norman MacCaig, Sorley MacLean, Hugh MacDiarmid and Kenneth White, for example (Gordon, this volume). In landscape art, a radical change in perception of wild landscapes in the late 18<sup>th</sup> and early 19<sup>th</sup> centuries, from inhospitable places to be avoided, to awe-inspiring places to be experienced, was encouraged by the romantic Scottish painters such as John Knox, Horatio McCulloch, Alexander Nasmyth, and the English painters, Edwin Landseer and J.M.W. Turner (Holloway & Errington, 1978). The creative influence of geodiversity is also continued in more modern landscape art and land art (Gordon, 2012; this volume). The popularising of interest in wild landscapes and natural features through literature and art helped to foster the early development of tourism in Scotland in the late 18<sup>th</sup> and 19<sup>th</sup> centuries (Hose, 2010; Gordon, 2012).

Geodiversity also contributes significantly to landscape character, in both rural and urban settings, and geoconservation plays an important part in maintaining the character of many of Scotland's iconic landscapes. This includes the built environment where the use of local or traditional stone and other geological materials (e.g. in vernacular buildings or stone walls) can contribute to the cultural heritage of an area. In recent decades there has been increased interest in indigenous stone, partly through a growing awareness of the importance of issues such as 'sense of place' and 'local distinctiveness', but also an increasing appreciation of natural stone as a modern architectural material. This has been reflected in a resurgence in the building stone industry in parts of Scotland, and a growing awareness of the importance of stone to the nation's cultural identity (Wilson, 2005; Hyslop *et al.*, 2006).

**Comment [MSOffice15]:** What about use of new but accessible technologies such as iGeology and Angus Miller's work on Rock Operator ([http://www.hoda.org.uk/hoda/Rock\\_operatoR.html](http://www.hoda.org.uk/hoda/Rock_operatoR.html))

### 3. Pressures on geodiversity

It is a common misconception that geological features and landforms are sufficiently robust not to require active management or action planning (Mace *et al.*, 2011). The pressures and threats facing geodiversity occur principally from development activities and land-use changes at both site and wider landscape scales (Werritty & Brazier, 1991; Werritty *et al.*, 1994; Lees *et al.*, 1998; McKirdy, 2002; Gordon & Barron, 2011). For example, these may arise through economic forces that determine the demand for minerals and changes in agri/forestry support measures that affect land use decisions. These may damage key features, impair their visibility and accessibility, fragment the interest and relationships between features and interrupt natural processes (Gordon & Barron, 2011). The vulnerabilities of different types of site, and required conservation measures, are considered by Prosser *et al.* (2006). Wider off-site impacts may also occur; for example, erosion down-drift of coastal defences (Lees *et al.*, 1998). Other impacts may arise from the effects of global processes (e.g. climate change and sea-level rise) (e.g. Gordon *et al.*, 1998; Pethick, 1999; Prosser *et al.*, 2010). These can act directly through enhanced erosion of coastal or riverbank exposures, or indirectly through demands for coastal protection or river management.

Sites located on the coast, adjacent to rivers or on active slopes are most likely to be impacted by climate change, sea-level rise and increased erosion or flooding. The human responses to these changes, in the form of 'hard' coastal protection or river and slope engineering are, however, likely to have a greater impact on geodiversity than direct climate changes alone (Prosser *et al.*, 2010). Climate change presents particular management challenges that will require working with governments, planners, decision makers and local communities to ensure that geodiversity interests are managed sustainably as part of wider, long-term adaptation strategies (Prosser *et al.*, 2010).

Human activities and development in the marine environment have the potential to impact upon both geomorphological and geological features at the seabed (Brooks *et al.*, 2009; Defra, 2010). They include: fishing (dredge and trawling), aggregate extraction, hydrocarbons (oil and gas installations), renewable energy installations, cables and pipelines, navigational dredging, dredge waste disposal and military activity. Given the dynamic nature of the marine environment, all of these activities have the ability to cause near and far-field effects through the interruption of existing sediment transport pathways and hydrodynamic processes. Furthermore, any disturbance of soft sediments on the seabed will also give rise to the suspension of fine particles in the water column, potentially altering local-regional sedimentation patterns. The planned nearshore expansion of large windfarms is a relatively new pressure, with uncertain impacts on marine geomorphological processes.

### 4. Policy context and the need for a strategic approach to geodiversity and geoconservation

Geodiversity is an integral part of nature and has a fundamental bearing on the wealth, health and wellbeing of Scotland's people. It either supports or helps to deliver the Scottish Government's Strategic Objectives in various ways, which serves to demonstrate the important role that it can play in future sustainable development through its contribution to key policy areas, including the economy (employment and products), environment (nature conservation, flood protection, marine planning, global processes), health (recreational resource, artistic inspiration) and education (scientific discovery and evolutionary processes) (Table 1). However, a review of the links between geodiversity and the current policy framework

identified a clear lack of integration of geodiversity despite its evident wide relevance (Natural Capital, 2011). A strategic framework or charter, similar to the Scottish Biodiversity Strategy, the Scottish Soil Framework or Scotland's Landscape Charter, would provide a means to highlight the wider role and benefits of geodiversity and associated geoconservation activities and to facilitate better integration into the policy framework as individual policies are revised or updated (e.g. within the Scottish Planning Policy (the consolidated SPP), the Scottish Biodiversity Strategy, landscape policy, greenspace strategy and cultural heritage policy)<sup>12</sup>. It would help to identify strategic priorities for geoconservation activities and provide a framework for actions by different stakeholders and sectors, including local authorities, public agencies and government departments; land managers; developers; industry and business; and individuals, communities and non-governmental organisations. Importantly, it should align with, and support, the Scottish Government's National Outcomes and Strategic Objectives (Tables 1 and 2). In particular, it should recognise the value of geodiversity for its:

- contribution to sustainable economic development;
- role in sustainable (integrated) management of land and water at a landscape/ecosystem scale, including management and adaptation to climate change and sea-level rise;
- role in supporting Scotland's habitats and species, and providing ecosystem/environmental services;
- intrinsic interest as part of Scotland's natural heritage;
- contribution to Scotland's valued landscapes and cultural heritage;
- contribution to education/public health/quality of life/national well-being.

Such a framework should instigate a process through which key stakeholders would work together to achieve better public awareness of geodiversity, its protection and better integration in policy and guidance to deliver sustainable management of land and water, consistent with the economic, social, cultural and environmental needs of Scotland. The key objective should be integration through a more holistic, ecosystem-based approach, rather than adding stand-alone blanket provisions for conservation of geodiversity or simply 'bolting-on' geodiversity. With an overall objective of promoting integration of geodiversity into relevant policies, the priority areas of activity are:

- 'future-proofing' ecosystem services, particularly in a context of climate change and rising sea-levels, through the implementation of more integrated approaches in the sustainable management of the natural heritage, land and water at a landscape/ecosystem scale for the wider benefit of Scotland's people, environment and economy;
- conservation and sustainable management of Scotland's geodiversity, both in designated sites and in the wider countryside and beneath our seas, to maintain and enhance its special character and qualities and the benefits it provides;
- raising awareness of the values of geodiversity and ecosystem services and the wider links with landscape, culture and sense of place, and encouraging a sense of pride through appropriate interpretation, promotional and educational activities, and public enjoyment and involvement;
- improving understanding of geodiversity and vital knowledge gaps, including the key area of the functional linkages between geodiversity and biodiversity.

Comment [MSOffice16]: I firmly agree. An earth systems approach is much more likely to work.

The outcomes from these activities are identified in Table 2. Such a framework, *Scotland's Geodiversity Charter*, has now been developed by the Scottish Geodiversity Forum in partnership with a range of stakeholders (Scottish Geodiversity Forum, 2012, Miller, this volume).

## 6. Conclusion

In addition to its intrinsic scientific and educational values, Scotland's geodiversity is an integral part of the wider diversity in nature that delivers economic, social and environmental services and benefits for society. However, it remains a major challenge to develop and implement a more holistic approach to geodiversity, biodiversity and landscape conservation management that recognises the benefits to society of protecting and enhancing ecosystems and working with natural processes at a time of likely unprecedented changes in the natural world as a result of climate change and sea-level rise. Geodiversity makes an essential contribution to these services and geoconservation-related activities are directly linked to delivering the Scottish Government's National Outcomes and Strategic Objectives. These links show the value of a more holistic, ecosystem approach and how geodiversity can add value. However, the absence of references to geodiversity in high-level policy documents and in development planning policies highlights the need for implementation of a more strategic approach to geodiversity. Such an approach is adopted in *Scotland's Geodiversity Charter* ~~should identify~~ which identifies priorities and outlines a framework for action by stakeholders and relevant sectors. It should help to: 1) provide an environment in which the rich geodiversity of Scotland can be understood, valued and managed sustainably; and 2) make geodiversity relevant to the way we work and live, providing a sense of place and contributing to the decisions we make about a sustainable future for our environment, for both people and nature. Instigating an incremental process through which key stakeholders ~~would~~ work together to achieve better protection of geodiversity through geoconservation activities and better integration of geodiversity in relevant policy and guidance should help to deliver sustainable management of land and water, consistent with the economic, social, cultural and environmental needs of Scotland. Promoting wider awareness, understanding and involvement will be a crucial part of the process. At policy, planning and decision-making levels, understanding of the way the Earth works should be one of the cornerstones of sustainable development.

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## Notes

<sup>1</sup> See <http://www.ukgap.org.uk/> [Accessed on 25 January, 2012].

<sup>2</sup> Geodiversity is the variety of rocks, minerals, fossils, landforms sediments and soils, together with the natural processes which form and alter them. Geoconservation is "action taken with the intent of conserving and enhancing geological and geomorphological features, processes, sites and specimens" (Burek & Prosser, 2008, p. 2).

<sup>3</sup> See 'Floods sink Thai's global factory', Sunday Times Business Section, 6 November, 2011.

- <sup>4</sup> An ecosystem approach is defined under the Convention on Biological Diversity as "...a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way." <http://www.cbd.int/ecosystem/> [Accessed on 25 January, 2012].
- <sup>5</sup> See <http://www.europeangeoparks.org/isite/page/52,1,0.asp?mu=4&cmu=30&thID=0> and <http://www.globalgeopark.org/english/> [Accessed on 25 January, 2012].
- <sup>6</sup> See reports of 'Workshops on 'Earth Sciences in the 21<sup>st</sup> Century' (<http://www.bgs.ac.uk/ukgeoscience/home.html>) and 'Earth Sciences in the 21st Century: a Scottish Perspective' (<http://www.abdn.ac.uk/geology/events/events/c21scotland.php>), held in January and February 2010 and co-ordinated by the Geological Society of London, the British Geological Survey and the Natural Environment Research Council. [Accessed on 25 January, 2012].
- <sup>7</sup> For example, see the leaflets produced by Scottish Local Geodiversity Groups - [http://www.scottishgeology.com/findoutmore/rigs\\_in\\_scotland/L&Binterpretive\\_lflts.html](http://www.scottishgeology.com/findoutmore/rigs_in_scotland/L&Binterpretive_lflts.html) [Accessed on 25 January, 2012].
- <sup>8</sup> For example, see the websites of North West Highlands Geopark (<http://www.northwest-highlands-geopark.org.uk/>), Lochaber Geopark (<http://www.lochabergeopark.org.uk/pages/Geotrails.asp>) and Geopark Shetland (<http://www.geoparkshetland.org.uk/>) [Accessed on 25 January, 2012].
- <sup>9</sup> See <http://iat-sia.com/index.php?page=scotland> [Accessed on 25 January, 2012].
- <sup>10</sup> See <http://www.centralscotlandgreennetwork.org/> [Accessed on 25 January, 2012].
- <sup>11</sup> See <http://www.scotland.gov.uk/Resource/Doc/278232/0083591.pdf> [Accessed on 25 January, 2012].
- <sup>12</sup> ~~At the time of writing (February 2012), the Scottish Geodiversity Forum is progressing the development of a Scottish Geodiversity Charter that addresses these issues. See consultation document at <http://scottishgeodiversityforum.org.uk/charter/> [Accessed on 12 March, 2012].~~

Comment [MSOffice17]: Lauch is due for 6th June

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**Table 1.** Geodiversity and Scotland's Strategic Objectives

Strategic Objective <sup>1</sup>	Contribution of Geodiversity
<b>Wealthier Scotland</b>	<p>Scotland's industrial development during recent centuries has been founded on its geological resources. Today, these are fundamental to economic development as a source of:</p> <ul style="list-style-type: none"> <li>• soil and water resources;</li> <li>• energy and minerals;</li> <li>• contributions to tourism and the growing area of geotourism, including geoparks;</li> <li>• construction materials for new building projects;</li> <li>• materials for the restoration of the built heritage;</li> <li>• collectable items (e.g. rocks, fossils, minerals, and semi-precious stones).</li> </ul>
<b>Safer &amp; Stronger Communities</b>	<p>Geodiversity contributes to better quality of life and stronger local communities through:</p> <ul style="list-style-type: none"> <li>• supporting services (e.g. soil formation, water cycling);</li> <li>• provisioning services (e.g. products such as fresh water and building materials);</li> <li>• regulating services (e.g. natural flood management, erosion control, coastal protection and water regulation, based on understanding and working with natural processes in an integrated way through shoreline management and catchment management planning);</li> <li>• cultural services (e.g. providing recreation and aesthetic experiences); people also value the 'sense of place' that is associated with recognised features of their environment, such as natural rock formations and landscapes, and the perceived 'feeling of security' and character created by those features.</li> </ul>
<b>Smarter</b>	<p>Geodiversity has educational values and provides opportunities to enhance learning achievements:</p> <ul style="list-style-type: none"> <li>• across the spectrum of schools (supporting the Curriculum for Excellence), colleges, universities (underpinning world-class research into how the Earth works) and life-long learning (helping everyone to explore and appreciate the world around them and gain inspiration from it);</li> <li>• through enhanced understanding of natural Earth surface processes such as erosion and flooding, geological processes that formed the landscape, climate change from geological records and the links between geological and cultural heritage, helping to contextualise human existence.</li> </ul>
<b>Greener</b>	<p>Geodiversity contributes to:</p> <ul style="list-style-type: none"> <li>• understanding the drivers and effects of environmental change (e.g. climate change, sea-level rise and carbon dynamics in organic (peat) soils);</li> <li>• planning for adaptive management in response to climate change and rising sea-level, based on understanding and working with natural processes (e.g. through development of river basin management plans and natural flood management involving restoration of natural processes and an understanding of floodplain histories from sedimentary records);</li> <li>• delivering sustainable, healthy places and environments in which to live, visit and do business; wise use of non-renewable geodiversity resources (e.g. minerals, soils, fossil fuels) is fundamental to sustainable development;</li> <li>• linking people, nature and landscape: geodiversity supports habitats, species and environmental quality and contributes to cultural heritage, sense of place and rural fabric; Geoparks and other tourism developments can help to sustain living and</li> </ul>

	vibrant communities.
<b>Healthier</b>	The management of Local Geodiversity Sites contributes to: <ul style="list-style-type: none"><li>• improving environmental health through soil and water quality;</li><li>• improving the quality and 'liveability' of local environments and greenspace, and providing recreation opportunities;</li><li>• fostering pride in the distinctiveness of local natural heritage and the aesthetic value of landscapes;</li><li>• fostering healthier lifestyles through the support of physical activity, such as recreation and adventure sports, and through spiritual enrichment, aesthetic experiences, mental inspiration and cognitive development.</li></ul>

<sup>1</sup> Source: <http://scotland.gov.uk/About/scotPerforms/objectives> [Accessed on 25 January, 2012]

**Table 2.** The contributions of geodiversity and geoconservation to selected National Outcomes

<b>National Outcomes<sup>1</sup></b>	<b>Contributions of geodiversity and geoconservation</b>
We value and enjoy our built and natural environment and protect it and enhance it for future generations.	<ul style="list-style-type: none"> <li>• Vital contributions to ecosystem services are safeguarded.</li> <li>• Understanding of natural processes informs adaptations to climate change.</li> <li>• Links between geodiversity and biodiversity are better understood.</li> <li>• The geo-archives in Scotland's rocks and landforms are protected for study and enjoyment.</li> <li>• Non-renewable resources are used sustainably.</li> </ul>
We realise our full economic potential with more and better employment opportunities for our people.	<ul style="list-style-type: none"> <li>• Economic benefits are delivered through tourism (e.g. in geoparks).</li> </ul>
We live in well-designed, sustainable places where we are able to access the amenities and services we need.	<ul style="list-style-type: none"> <li>• Vital contributions to ecosystem services are safeguarded.</li> <li>• Understanding of natural processes informs adaptations to climate change.</li> </ul>
We reduce the local and global environmental impact of our consumption and production.	<ul style="list-style-type: none"> <li>• Non-renewable resources are used sustainably.</li> </ul>
We live longer, healthier lives.	<ul style="list-style-type: none"> <li>• Public health benefits from outdoor activities and use of greenspace.</li> </ul>
We are better educated, more skilled and more successful, renowned for our research and innovation.	<ul style="list-style-type: none"> <li>• Educational benefits from resources for universities, schools and lifelong learning and fundamental geoscience research.</li> </ul>
We take pride in a strong, fair and inclusive national identity.	<ul style="list-style-type: none"> <li>• Geodiversity underpins the character of Scotland's natural and built landscapes, which contributes to national identity.</li> </ul>

<sup>1</sup> Source: <http://scotland.gov.uk/About/scotPerforms/outcomes> [Accessed on 25 January, 2012]