Viewpoint Paper

Engaging with geodiversity – Why it matters

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ABSTRACT
The Conference, 'Engaging with Geodiversity – Why it Matters', December 2010, addressed the wider relevance of geodiversity in Scotland. A key challenge is to integrate geodiversity within existing policy relating to the way we work and live, and therefore to inform better the decisions we make about a sustainable future for our environment. This will require partnership working among the geoscience, geoconservation and voluntary sectors at both national and local levels, not only to demonstrate convincingly the economic, social, cultural and environmental values and benefits of geodiversity, but also to deliver real outcomes for both people and nature. The key drivers that provide particular opportunities, as well as challenges, for the integration of geodiversity are the development of an ecosystem approach and how society responds to climate change. Addressing these will be crucial from a geoconservation perspective to develop a wider understanding of the essential environmental role played by geodiversity and for the protection of key sites, both from a policy perspective in delivering economic, social and environmental benefits, and from an academic perspective in ensuring support for geoscience. The key message - that geodiversity matters - must be communicated strongly to the highest levels of government, among key interest groups and at a local community level.

Keywords: Geodiversity, Geoconservation, Ecosystem services, Climate change, Future opportunities and challenges

1. Introduction

In a recent Viewpoint article in this journal, Prosser et al. (2011) outlined an agenda for discussion in the context of the September 2011 conference of the Geologists' Association on 'Geoconservation for Science and Society: an Agenda for the 21st Century' and in response to new political, social, economic and environmental policy drivers. As a contribution to the discussion, we present some perspectives on the key messages from the Conference, 'Engaging with Geodiversity – Why it Matters', organised by Scottish Natural Heritage (SNH), the British Geological Survey (BGS), the Royal Scottish Geographical Society (RSGS) and the British Society of Soil Science (BSSS) and held at Our Dynamic Earth in Edinburgh on 1 December 2010[1]. The aim of this Conference was to examine the

[1] Details of the programme and abstracts are available at:
http://www.bgs.ac.uk/research/highlights/2010/geodiversityConference.html

scope, values, relevance and applications of geodiversity within Scotland, particularly in the context of ecosystem services and climate change, two of the prime drivers for current environmental policy, and to demonstrate how geodiversity might be better integrated within relevant key areas (viz. nature conservation, planning, urban regeneration, landscape, environment, education, sustainable rural development and quality of life/national well-being). Although the focus was primarily on Scotland, we believe that the issues discussed here are of much wider relevance for the UK and international geoscience community.

We strongly agree both with the wider agenda set out by Prosser et al. (2011), and that this is a crucial time to set out a 'route map' to establish geodiversity on the environmental policy agenda. We particularly welcome the proposed focus on a holistic, multidisciplinary approach as we believe that geodiversity-related activities must be outward looking and the wider benefits to society publicised in a fashion transparent to all. The call for such an approach is not new (e.g. Gordon and Leys, 2001), but its development and implementation are now vital not only in terms of integrating geodiversity, biodiversity and landscape conservation management, but also in terms of supporting wider environmental policy and in delivering economic, social, cultural and environmental benefits for society at a time of unprecedented (in recent human experience) projected changes in climate and sea level (e.g. Gordon and Barron, 2011). The adoption of an ecosystem approach under the Convention on Biological Diversity, and reflected in the Millennium Ecosystem Assessment (2005) and the UK National Ecosystem Assessment (2011), provides an outstanding opportunity to demonstrate the wider relevance and value of geodiversity for society, to help deliver real economic, social and environmental benefits, including adaptation to climate change, and to ensure robust policies and decisions for the natural environment. Such integration is also important in engaging wider support for geoconservation and better appreciation of the role of allied geoscience disciplines.

Our starting point is that a holistic approach is essential, recognising that geodiversity links people, landscapes and their cultures through the interactions of biodiversity, soils, minerals, rocks, fossils, active processes and the built environment (Gordon and Leys 2001; Gray 2004; Stanley 2004; IUCN 2008; Gordon and Barron, 2011). In particular, geodiversity both provides and underpins fundamental ecosystem services through its influence on landscape, habitats and species, economic activities, historical and cultural heritage and people's health and well-being. It also has a key contribution to make in climate change adaptation and in sustainable management of the land, river catchments, the coast and the subsurface. Nevertheless, greater awareness and understanding of the widespread relevance, influence and benefits of geodiversity remain low outside the geoscience community, and its recognition and incorporation in policy are poor (e.g. in the 2011 Natural Environment White Paper in England).

2. Geodiversity and geoconservation in the wider landscape

For a country of its size, the geological development of Scotland has given rise to a remarkable geodiversity, both on land and beneath Scottish territorial and offshore waters (Gordon and Barron, 2011; Brooks et al., 2011). This very geodiversity provided the stimulus for the birth of geological science within Scotland. Many places in Scotland, both onshore and offshore, are of great importance to geoscience research and education for their rocks, fossils and geomorphology, demonstrating Earth processes or events of international significance. Traditional site-based approaches, therefore, remain the cornerstone of geoconservation and are essential to protect the best and most important localities for scientific study, education and as part of our natural heritage (cf. Gray, 2004; Brocx, 2008). These are particularly well exemplified in the site networks of the national Geological Conservation Review and Local Geodiversity Sites (LGS). We therefore fully endorse the concerns of Prosser et al. (2011) that the supporting site audits are maintained, and

expanded in the case of LGS in Scotland, in order to underpin geoconservation. While helping to conserve important examples of local geodiversity and enhancing the geodiversity resource, LGS should also be seen as having a wider function in contributing to local people's enjoyment and understanding of geodiversity, to the quality of local environments (their 'liveability') and ultimately to the quality of life of local communities (Arkley et al., 2010). There is an important challenge here for Local Geodiversity Groups, and other groups in the Third Sector, to broaden their agenda and to engage with wider activities, such as the Central Scotland Green Network.

While recognising the importance of site-based geoconservation and the achievements to date (Burek and Prosser, 2008; Prosser et al., 2011), and the need to maintain the national and local systems of protected sites, we concur fully with Prosser et al. (2011) that the main strategic challenge for the future is to address the role of geodiversity in a more integrated approach at the landscape scale (including the marine environment). In particular, to gain broader support for geoconservation, both at a policy level and at a local community level, it will be essential to use knowledge of geodiversity and geoscience evidence in an integrated way to inform management responses to key policy issues and to deliver actual benefits for the natural environment and society. We develop this theme below in relation to ecosystem services and climate change.

3. Geodiversity and ecosystem services

Geodiversity is now increasingly acknowledged in the geoscience community to underpin and deliver essential ecosystem services and functions for the wider benefit of people and the environment (Gordon and Barron, 2011; Gray, 2011). Some authors (e.g. Gray, 2008, 2011) use the term 'geosystem services' for the goods and functions provided by geodiversity, but in line with the holistic definition of ecosystems, we prefer to consider geodiversity as an integral component of ecosystem services, rather than introduce a separate term. However, it is important to recognise that geodiversity also provides essential goods and services (e.g. minerals, aggregates and fossil fuels) that are considered to be non-renewable capital assets in the Millennium Ecosystem Assessment (2005), as well as additional 'knowledge' benefits (e.g. records of past climate changes and understanding of how Earth systems operate) (Gray, 2011).

Geodiversity underpins many of the different types of ecosystem service in the Millennium Ecosystem Assessment (2005). It is a fundamental component of supporting services, but also contributes to provisioning, regulating and cultural services (Gordon and Barron, 2011; Gray, 2011). For example, geodiversity provides:

- the knowledge base to help society adapt to climate change and to mitigate natural hazards through better understanding of natural processes;
- the physical basis for our varied landscapes (both rural and urban) and scenery, and has a profound influence on terrestrial and marine habitats, wildlife and use of land and water;
- the resources for many aspects of economic development, including tourism-based activities;
- a powerful influence on our cultural heritage as a source of inspiration for art, sculpture, music, poetry, literature and education (Earth system science), and on the character of our built environment through the use of different building stones; and
- the resources for a variety of recreation and outdoor activities, with consequent benefits for people's health and well-being.

In some cases the benefits from geodiversity are direct (e.g. provision of fresh water), whilst in others they are achieved through the influence that geological, hydrogeological, geomorphological or pedological factors and processes have on both landforms and the biodiversity they support. Not only is geodiversity crucial for sustaining living species and habitats, but also it has a fundamental bearing on people's health and wellbeing. Therefore, it has a strong contribution to make in a wider policy context in supporting the Scottish Government's Strategic Objectives and their important economic, social and environmental outcomes.

As a key policy driver in the UK, the ecosystem approach now provides the basis for integrating geodiversity and biodiversity, and a means of demonstrating the essential role of geodiversity in delivering ecosystem services. Adopting an ecosystem approach means taking a holistic view of ecosystems, including geodiversity (the abiotic elements of ecosystems) as well as biodiversity (the biotic elements of ecosystems), during decision-making and valuing the services they provide. Geodiversity has to be recognised for its active role in ecosystem services, rather than the passive role that is often assumed. An ecosystem approach linking geodiversity and biodiversity is highly relevant to a number of cross-cutting issues of current concern to decision makers in government:

- the management of natural system responses and habitats to enable adaptations to climate change;
- catchment/river/floodplain restoration to enable sustainable (natural) flood management, coastal management and habitat/landform adaptation to projected sea-level rise and possible changes in the magnitude, frequency and duration of geomorphologically significant (extreme) events;
- hazard prediction and mitigation, including erosion, flooding and slope stability risk analysis;
- soils and habitat restoration, including the multifunctional management of peatlands for habitat and carbon sequestration benefits;
- urban regeneration, Sustainable Drainage Systems (SuDS) and the restoration of contaminated land; and
- understanding the functional links between marine biodiversity and geodiversity and informing the assessment of search areas for Marine Protected Areas.

These are key challenges for the geoscience community. However, it is encouraging that the value of geodiversity is now being recognised by the biodiversity community in the management of freshwater (Vaughan et al., 2009), coastal (Jones et al., 2011) and upland (Orr et al., 2008) environments. In relation to site management, Hopkins et al. (2007) have also advocated "a need to move from management largely focused on selected species and habitats towards much greater emphasis on the underlying physical processes that are essential to the maintenance of biodiversity" (p. 22). Individual sites are nearly always linked by surface and sub-surface processes operating in the landscape and this coupling provides both spatial and temporal contexts for understanding conservation issues, whether on hillslopes, valley floors or along coasts. Landscape sensitivity to change, and hence the stability of individual sites, reflects these relationships and how they respond to extreme events and longer-term environmental changes. Therefore, it is not only the intrinsic benefits of geodiversity that we should value, but also the functionality of geodiversity as an essential part of natural ecosystems. A key message is that geoconservation contributes to maintaining the resilience and adaptive capacity of both landforms and biodiversity as well as supporting critical ecosystem services. Geodiversity, supported by geoconservation, delivers many fundamental ecosystem services, but this needs to be communicated much more effectively at national and local levels. At a national level, there is a strong case for

much better integration of geodiversity into the ecosystem approach and the assessment of ecosystem services, as set out in the UK National Ecosystem Assessment (2011). There is an important role here for the conservation agencies and the geoscience community, not only in making the case at a policy level, but also in providing the evidence and implementing more integrated approaches in conservation management. At a local level, there is a need for practical demonstration, for example by Local Geodiversity Groups, of how investment in geodiversity activities can result in wider benefits for communities (e.g. through management and improvement of greenspace).

4. Geodiversity and climate change

Successful adaptation to climate change and related flooding, landslides and sea-level rise will require an understanding of geodiversity, and particularly the way that geomorphological processes respond to these changes (Newson and Large, 2006; Orford and Pethick, 2006; Cooper and McKenna, 2008; Delta Committee, 2008; Winter et al., 2008; Prosser et al., 2010). For example, ecosystem resilience, sensitivity and responses to climate change and sea-level rise are conditioned by geomorphology and soils, including changes in the stability/instability of landforms, fluxes of sediment and water and the properties of the geological substrate and soil (Gordon et al., 1998; Hansom and Angus, 2001; Pethick, 2001; Jonasson et al., 2005; Morrocco, 2005). Changes in the magnitude, frequency and duration of processes, process rates and the nature and spatial distribution of processes are likely to have significant implications for the resilience and adaptability of most ecosystems. These may result in reductions in recovery time for habitats and species between extreme events, changes in the distributions of landforms in response to altered patterns and rates of both erosion and deposition, and longer landform readjustment times to extreme events due to reactivation by subsequent events. Geomorphological processes and soils may become vulnerable to irreversible changes or changes in process regimes, so that an understanding of geomorphological sensitivity and the capacity of the system to absorb externally imposed stresses is a key consideration (Thomas, 2001; Werritty and Leys, 2001; Harvey, 2001; Burt et al., 2002; Church, 2002). In extreme cases, the frequency and speed of disruption may mean that habitat recovery may never be fully established, leading to a change in state. As demonstrated in palaeoenvironmental records, such changes in state in dynamic systems may be inevitable, but a geodiversity perspective allows the pace and scale of change to be better understood and managed.

Awareness of the temporal dimension is also important; ecosystems are neither fixed nor stable but are continually adapting to changes in geomorphological processes over decadal, centennial, millennial and longer timescales in response to a range of natural and human drivers (Dearing, 2006; Dearing et al., 2010). To understand how ecosystems respond to change, it is vital to think in terms of geomorphological processes and their changes over both space and time. Ecosystems are not only affected by contemporary changes, but are also conditioned by changes in the past in response to different levels of disturbance (e.g. Chiverrell et al., 2007). These past changes still produce responses today and will continue to have an impact into the future. Awareness of past change is therefore essential to understand future ecosystem trajectories. For example, most of the present coastal ecosystems of Scotland have been conditioned by isostatic uplift, but the postglacial uplift of Scotland may now be outpaced by global sea-level rise (Rennie and Hansom, 2011). If the observed recent patterns are maintained, this has significant implications for the natural and cultural heritage, strategic planning, flood risk management and sustainable development on Scotland's coast, and particularly on low-lying coastal zones, estuaries and river mouths around the major cities. Changes now appear to be occurring faster than they have in the past, and future coastal planning strategy needs to embrace such knowledge. There may not be time for habitats and species to adjust in situ or suitable accommodation space for them to relocate (Orford and Pethick, 2006). Consequently, there is potential for major irreversible changes

on human timescales if thresholds (or tipping points) in dynamic systems are crossed, requiring a step change in conservation management and planning. Information about species tolerances and thresholds in terms of habitat requirements (soils, hydrology, landform mosaics) will be essential for restoration, or managed relocation/adaptive management.

In addition, analysis of palaeoenvironmental archives and geomorphological records provides a long-term perspective on trends, rates of change and future trajectories in ecosystems and service delivery, a gap acknowledged in the Millennium Ecosystem Assessment (2005). Palaeoenvironmental data can provide a detailed understanding of these changes and inform the range of potential options for management and/or restoration, in effect "learning from the past" (Anderson et al., 2006; Dearing, 2006; Dearing et al., 2006; McCarroll, 2010; Newman et al., 2010). While there are unlikely to be any exact analogues for a future warmer world, Quaternary palaeoenvironmental records, in particular, are important in understanding how climate, physical processes, sea level and habitats have changed in the past and enabling informed evaluation of scenarios of future change over different temporal and spatial scales (Willis and Birks, 2006; Willis et al., 2007, 2010; Froyd and Willis, 2008; Davies and Bunting, 2010). For example, comparison of UKCP09 relative sea-level rise rates with those for the mid- and late- Holocene allows a means of scaling potential future coastline changes (Gehrels, 2010; Rennie and Hansom, 2011), and changes in slope stability, sediment production, landform distributions and floodplain and wetland histories can provide pointers for future catchment responses (Higgitt and Lee, 2001; Lane et al., 2007; Macklin et al., 2010).

Effective conservation strategies for managing ecosystem responses will need to work in sympathy with natural processes. This is recognised, for example, in the Flood Risk Management (Scotland) Act 2009. Therefore, this may include options for adapting to climate change through natural flood management techniques, including 'creating room for rivers' through floodplain reconnections and adaptive management to create accommodation space ('managed realignment') at the coast. Significantly, the benefits of this approach are now acknowledged by the biodiversity community; for example, Hopkins et al. (2007) recommend that "allowing natural processes to shape the ecology and structure of whole landscapes, will create the best possible chance for conserving the greatest amount of biodiversity" (p. 14). 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 river flooding and coastal flooding and erosion in a sustainable manner, but also in terms of avoiding the additional costs of ignoring them and consequently having to deal with unintended effects (e.g. loss of beaches in front of hard coast defences).

Fortunately, as demonstrated in the Conference presentations, much is already known about the relationships between active land forming and soil forming processes, biodiversity and climate factors. In addition, the recent geological archive documents the relationships between past changes in climate and changes in habitat and species distributions, changes in slope stability and sediment availability, floodplain and wetland histories and coastline changes. An important challenge is to draw this knowledge together systematically, incorporating geomorphological and ecological resilience and sensitivity, to help inform ecosystem management and legislative and regulatory decisions relating to climate change, flooding and sea-level rise. The particular management challenges of adapting to climate change will require working with governments, planners, decision makers and local communities to ensure that geodiversity interests are managed sustainably as part of long-term, integrated, adaptation strategies informed by robust evidence provided by the academic community (Prosser et al., 2010).

5. Geodiversity and the policy framework in Scotland

Geodiversity does not just reflect events that happened in the distant past - it is highly relevant today and for future generations. It is crucial for sustaining living species and habitats, and it has a vital role in underpinning the economic livelihood, health and wellbeing of Scotland's people through its significant contribution to, and underpinning of, ecosystem services. It therefore has a major contribution to delivering the Scottish Government's Strategic Objectives and key themes for a Greener Scotland, as noted by Scottish Environment Minister, Roseanna Cunningham MSP, in her opening address to the Conference. However, this is not yet widely understood or reflected in policy documents. We have highlighted two areas, ecosystem services and climate change, where there are significant opportunities and challenges for demonstrating the importance of geodiversity in relation to current policy drivers. Others include marine geodiversity and soils. For example, the Marine (Scotland) Act 2010 and the UK Marine and Coastal Access Act 2009 provide opportunities for greater engagement in marine conservation and developing a better understanding of the functional links between marine geodiversity and biodiversity in relation to the development of Marine Protected Areas (Marine Scotland et al., 2011). Similarly, by acknowledging the multifunctionality of soils and their importance in relation to climate change, water quality and sustainable flood management, and habitat and biodiversity support, the Scottish Soil Framework (Scottish Government, 2009) expressly links together geodiversity and biodiversity, particularly in relation to key issues of climate change and changes in land use and land management practices (Dobbie et al., 2011).

6. Conclusions

A major challenge is to develop a more holistic approach to geodiversity and the ecosystem services that it supports. This should emphasise the benefits to society of protecting and enhancing geodiversity and of 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. It is vital for the welfare of society today and for future generations to maintain these services and to ensure the integration of geodiversity in the ecosystem approach. Understanding the way the Earth works is fundamental to the long-term and sustainable management of our natural environment. Better application of existing knowledge will enable the development of more appropriate and integrated strategies and policies for sustainable management, based on working with, rather than against, natural processes. This is essential if effective policies addressing climate change, energy and food security, environmental stewardship and wealth creation are to be put in place. Equally, there is a need for raised awareness of the benefits of such approaches among key interest groups and their advisors. This will require partnership working among the geoscience, geoconservation and voluntary sectors. The geoscience community must provide the knowledge needs and analysis synthesised in a form that conservation practitioners, policy makers and others can access easily. The conservation agencies must continue to develop more integrated approaches to geodiversity, biodiversity and landscape conservation management, informed by this knowledge. The voluntary sector must look beyond sites and embrace ecosystem services thinking and how geoconservation can contribute to local quality of life and deliver public value. All must promote the case for geodiversity at a policy level if the required step change in awareness and policy is to be achieved.

Promoting wider awareness, understanding and involvement is crucial. At policy, planning and decision-making levels, there is a need to establish understanding of the holistic way that natural systems work as one of the cornerstones of sustainable development. This will require much better engagement not only with the biodiversity community, but also with policy makers and the business community. Raising public awareness and engagement at a community level are also vital. There is an important role here for education and outreach through schools (and in Scotland the new Curriculum for Excellence), outdoor learning,

lifelong learning and the voluntary sector (Local Geodiversity Groups) (Anderson and Brown, 2010). Bodies and learned societies such as the Royal Scottish Geographical Society, the British Society of Soil Science, the British Society for Geomorphology, the Quaternary Research Association, the Geologists' Association, the Geological Society and the Scottish Earth Science Education Forum all have a significant part to play in knowledge exchange and outreach. Fundamental to such learning is the availability of sites for field study, which in turn links directly back to the need for effective geoconservation. Since geology and its allied disciplines are to a large degree site-based, field sites with features exposed and accessible will continue to be essential for continued scientific research, education and raising awareness activities.

In the final discussion at the Conference, the following key priorities were identified. Although framed in a Scottish context, they potentially have much wider applicability.

- The vital importance of embedding our geological knowledge into the wider policy framework initiatives.

- The need for development of an overarching national framework for geodiversity, analogous to the Scottish Soil Framework, that will align geodiversity more closely with biodiversity within the existing policy framework and the Scottish Government's Strategic Objectives.

- The need for clear leadership on geodiversity issues and a more active role by the learned societies.

- The need to agree the core advocacy messages and to promote them among policy makers and their advisers within the Scottish Government. The messages should be clear, simple and effective, setting out why geodiversity matters and the actions needed to better establish its role.

As Iain Stewart, Professor of Geosciences Communication, University of Plymouth, succinctly commented:

> "We have arguably the finest range of geodiversity, and some of the most important geological sites in the world, and this is a natural heritage worthy of respect and protection. Equally, rocks and related resources have a vital role in underpinning the economic livelihood and health of the nation. Both these messages need to be strongly communicated to the highest levels of government if effective policies addressing climate change, energy security, environmental stewardship and wealth creation are to be put in place. Geology, it seems to me, is the bedrock to the long-term and sustainable management of our natural environment."

In conclusion, we therefore advocate an outward-looking approach to geodiversity in the 21st century that engages with a broader agenda including the wider environmental, economic and social issues of concern to society. That geodiversity is integral to the whole natural environment is fundamental to the challenges we face in order to make the ecosystem approach fit for purpose and climate change adaptation actually deliver. This is vital if geodiversity is to become more widely recognised as an integral part of the natural environment and therefore help to inform better the decisions we make about a sustainable future. Its contribution will require to be developed into more integrated approaches, with a focus on delivering real benefits for society.

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