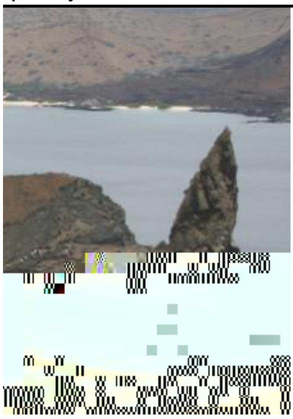
www.iucn.org/parks



INTRODUCTION

The revision of the IUCN definition of a protected area brought about a fundamental change in the primary focus from biodiversity to the broader concept of nature (Dudley, 2008). The contrast between the previous

Unpacking the definition a little further to be of relevance to protected areas requires two further terms to be defined.

Geoheritage FRPSULVHV WKRVH HOHPHQWV RI geodiversity that are considered to have significant scientific, educational, cultural or aesthetic value (Díaz-Martínez, 2011; ProGEO, 2011; Geological Society of $PHULFD 3XW LQ HYHU\GD\ ODQJXDJH µRXU geoheritage is the story of the Earth; a narrative through time preserved in its rocks, landforms, fossils, minerals and soils that provides a strong case for JHRFRQVHUYDWLRQ¶ &URIWV *RUGRQ 7KHUH LV D responsibility to ensure this inheritance from the past is passed on to future generations. In practice, a site or area of high geoheritage significance can comprise a single feature of value, and does not need to have a diversity of features present.

How these interests are managed is encompassed by the term geoconservation GHILQHG EURDGO\ DV µ´KH conservation of geodiversity for its intrinsic, ecological DQG JHR KHULWDJH YDOXHV´ 6KDUSOHV S 0RUH VSHFLILFDOO\ LW KDV EHHQ GHILQHG DV µDFWLRQ WDNHQ ZLWK WKH intent of conserving and enhancing geological, geomorphological and soil features and processes, sites and specimens, including associated promotional and awareness raising activities, and the recording and rescue of data or specimens from features and sites WKURXJK WKH GHWHULRUDWLRQ¶V ORVV RU GDPDJH¶ 3U

It should be clear from these definitions that geoconservation essentially involves the care, management and promotion of geoheritage in protected areas (ProGEO, 2011). In addition, it includes the conservation of geodiversity in a broader sense 353<00ri s02s3fm<h4oa

while many others have significant value for aesthetic reasons and for recreation and tourism activities (Coratza & Panizza, 2009; Dowling & Newsome, 2010).

As geodiversity is widely regarded as the abiotic equivalent to biodiversity (Gray, 2013; Crofts, 2014), it has equal justification for being a key element in protected areas as an integral part of nature and natural heritage: the fourth reason. By definition, geodiversity is a vital component of ecosystems in which biotic and abiotic components form an interacting system (Tansley, 1935; Convention on Biological Diversity, 1992). The linkages and interdependencies between abiotic and biotic nature are clear across a wide range of scales from global to local (e.g. Soukupová et al, 1995; Barthlott et al., 2005; Alexandrowicz & Margielewski, 2010). The substrate of rocks and soils provides the rooting zone and much of the nutrient supply for plant growth and survival. The specific characteristics of the substrate and soil ± acidity/alkalinity, moisture retention capacity, chemical composition, and others, determine its capacity to host plants and animals. So, in some cases, the chemical composition of the rocks will determine particular plant types which are so unusual that they justify protection, as for example those growing on the serpentine rocks of the Keen of Hamar in Shetland, UK[4], and the thermophilic plants dependent on the enriched chemical cocktail in the Waimangu volcanic valley, Rotorua, New Zealand[5]. Equally important are the dynamic processes (e.g. soil formation, biogeochemical and water cycling, stream flows, erosion and sedimentation) that provide nutrients and maintain habitat condition and ecosystem health. Hence, in many environments the complex and dynamic patterns of micro- and meso-scale topography, soils and geomorphological processes provide mosaics of habitats, corridors and topographical variations for high species richness (Thorp et al., 2010; le Roux & Luoto, animal remains dating from around 310 million years ago during the Carboniferous period. The first reptiles known were discovered here and the fossils represent the evolution of life from amphibians to reptiles. Joggins Fossil Cliffs also provides the possibility of discovering new species and of new interpretations of plant and animal history by future generations of scientists, especially as it is subject to shoreline erosion by the high-energy tidal currents and waves in the Bay of Fundy exposing new sections continually. The site was also important in the development of ideas about the evolution of life on Earth through the visits of scientists in the mid-19th century ± including Charles Darwin and between subglacial volcanic eruptions and ice caps, producing high-magnitude floods that shape the existing sandur plains and build the land out into the adjacent ocean. The rivers flowing from the ice margin provide nutrients to support plant growth and the sandur plains provide food and habitat for breeding arctic animal species, such as the Great Skua (Catharacta skua) and the Red-throated diver (Gavia stellata). The arctic environment adjacent to the ice cap is ideal for the formation of periglacial forms such as palsas (low mounds formed by ice lenses just below the ground surface). It also provides informal recreational RSSRUWXQLWLHV LQFOXGLQJ WKH mountain, and snow scooter tours in winter. Cultural history is also significant, particularly in the many folk tales and legends, the grazing of sheep on the upland heaths and sandur plains, and the skills of local people in navigating their way across the highly hazardous sandur plains with their shifting channels and sinking sands. There is access by the public to the edge of some of the outlet glaciers and ice-dammed lagoons, as well as to the ice cap and the surrounding land. Interpretation facilities explain the geoheritage significance of the protected area, especially at Skaftafell in the south (Guttormsson, 2011).

The national park is protected under a specific Icelandic Act of Parliament. There are remaining threats which, without the existence of the park, would be significantly higher. The park helps to protect the main river systems from exploitation for hydro-electric power, although what legitimately should have been areas protected within the park have now been dammed for hydro-electric power production.

The Giant Mountains, Czech Republic -Poland : The Giant Mountains, located astride the Czech-Polish border, are part of the Sudetes mountain belt formed in the late Carboniferous during the Hercynian orogeny. nahoII d s7aror-3(r)3(e)4(e)-3(")s7aoundn rt 9 inceres 1se They are the highest and most northern mountain massif in central Europe. They are outstanding for inter-related geodiversity, biodiversity and cultural interests. The area KDV EHHQ GHVFULEHG DV µD SDLQ HµDLQV ODUFGWLFL Q PLGGOH RI (XURSH IRUPLQJ D µELRJHRJU with affinities to the Alps to the south and the Scandinavian mountains to the north (Soukupová et al., âWXUVD ([FHSWLRQDOO\ IRU mountains of Central Europe, the summits and plateau surfaces rise above the alpine tree line and display a remarkable assemblage of relict and active periglacial features, including tors, cryoplanation l-6(ana11)-2(y)3(al)8( )s(io

The Skeiðarársandur outwash plain and river systems emanating from the Skeiðarárjökull, Vatnajökull National Park, Iceland: an intensely dynamic environment with rapid changes in water discharge and velocity, such as occurred in 1996 when a subglacial eruption melted the overlying ice and caused a major flood © Roger Crofts

The Giant Mountains: lichen-covered blockfields and cryoplanation terraces occur on the higher summits, with vegetated patterned ground, stands of dwarf pine (*Pinus mugo*) and subalpine mires on the plateau slopes below. The adjacent glacial corries support a great diversity of plants on the leeward slopes associated with snow avalanche paths and snow beds

Protection and management are co-ordinated under the cross-border Czech-Polish Krkonoše Karkonosze National Parks and the Krkonoše Karkonosze Transboundary Biosphere Reserve. Management recognises the importance of maintaining natural geomorphological processes as the driving force for supporting diversity in the Park. Popular publications and material for visitors also emphasise the links between geodiversity, biodiversity and cultural heritage in an exemplary manner[8].

IDENTIFYING SITES AND AREAS FOR GEOCONSERVATION

The basic approach recommended by IUCN WCPA for identification of protected areas rests on the categorisation of biogeographical regions (Davey, 1998) and key biodiversity areas (Langhammer et al., 2007). However, a somewhat different approach is required for the identification of sites for geoconservation. A staged approach is suggested both for the identification of the

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2. Natural systems and processes should be managed in a spatially integrated manner : Management of part of a natural system in isolation from other elements of the system should be avoided. For example along a coastline or in a mountain area or a river basin, management should seek to achieve complementary objectives, such as geodiversity, biodiversity and landscape diversity conservation, and recognise the effects of connectivity and dependencies between different parts of the system at the landscape scale (e.g. downstream habitat changes arising from changes in sediment transfer between hillslopes and river channels).

3. The inevitability of natural change should be recognised : No system or element of a natural system is static forever and change will occur. The traditional approach of maintaining or enhancing the current state to preserve features can remain valid where these are unlikely to be significantly affected by the natural changes, such as iconic mountains and robust rock features, or in the case of some small, high-value sites where protective measures can be effectively implemented. But, in many circumstances, where natural processes are a key element of maintaining or protecting the features of interest, it will have to be recognised that working with natural changes to allow geomorphological processes to adapt to the changed conditions may be the only effective strategy (Prosser et al., 2010; Sharples, 2011). This may mean the loss of some features, changes in their locations possibly outside the boundaries of the protected area, or their realignment. Where protection is GHHPHG QHFHVVDU\ LW PD\ PHDQ VRPH IRUP RI µVRIW¶ JHR engineering, but this should only be undertaken provided that it is mimicking natural processes rather than seeking to modify them substantially or to destroy them (see above).

4. The effects of global climate change should be carefully considered : Climate change is an increasingly important issue and cannot be ignored just because there might remain some doubt about the relative contribution of natural and anthropogenic forcing. The resulting effects will inevitably challenge the management objectives of protected areas. Careful consideration will be needed where, for example, the features are lost and/or processes are lessened or intensified), and so changes to the basis for protection

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Table 2: Examples of geoconservation protected areas in the IUCN Management Categories
Sources: compiled from various sources and taken from Crofts & Gordon (2015) with updates by the authors

Category	National examples	World Heritage Site examples
Ia Strict nature reserve	Greenland Ice Cap, Greenland: ice cap and nunataks; Geysir valley, Kronotsky Zapovednik, Russia: volcanic features	Macquarie Nature Reserve, Australia: Earth mantle rocks; Surtsey, Iceland: biotic and abiotic processes on new island formed 1963-67
Ib Wilderness area	Maspalomas Dunes Special Nature Reserve, Spain: salt marshes within Pleistocene dunes; Noatak Wilderness, Alaska, USA: river basin	Putorana Plateau WHS, Russia: basalt plateau
II National park	Giant Mountains, Czech Republic-Poland: periglacial landforms and geodiversity-biodiversity relationships	Dolomiti Bellunesi National Park, Italy: karst, glaciokarst and reefs; Grand Canyon National Park, USA: stratigraphic record and arid land erosion; Yoho National Park, Canada: Cambrian fossil beds (Burgess Shale) in landscape protected area
III Natural monument or feature	[illegible]	

around the world are testimony to this. In addition, however, geoconservation can be part of protected area rationales and management objectives for all of the other Categories. Table 2 provides examples for nationally protected areas and for World Heritage Sites to exemplify this point.

Although not a protected area category as such, Geoparks are areas with outstanding geoheritage established primarily to combine conservation of geoheritage with promotion of geotourism to support sustainable local economic and cultural development (McKeever et al., 2010). Geoparks may wholly, or in part, include protected areas and help to ensure their conservation. They may be set up through community-led initiatives or top-down designation. The Global Network of National Geoparks or Global Geoparks Network (GGN), assisted by UNESCO, provides an international framework of accreditation and standards for geoparks (UNESCO, 2010); currently the network comprises 100 national Geoparks worldwide (UNESCO 2014).

THREATS TO GEOHERITAGE CONSERVATION

There are many threats to the protection of geoheritage arising from human activities (Table 3). These need to be systematically considered in protected area management.

Table 3: Principal human-induced threats to geoheritage in protected areas
Source: adapted from Gordon & Barron (2011), Brooks (2013) and Gray (2013)

Threats and pressures	Examples of impacts on geoheritage in protected areas
Urbanisation, construction (including commercial and industrial developments inland and on the coast), infrastructure, renewable energy installations	x destruction of landforms and exposures of sediments and rocks x fragmentation of site integrity and loss of relationships between features x disruption of geomorphological processes x destruction of soils and soil structure x changes to soil and water regimes
Mining and mineral extraction (including extraction from opencast mines, pits, quarries, dunes & beaches, river beds, marine aggregate extraction and deep-sea mining)	

ESTABLISHING MONITORING AND EVALUATION SYSTEMS

Finally, as with any protected areas, systems for monitoring and evaluating the state of protection are necessary and in particular to determine whether the geoheritage features and forms, and the natural processes operating to ensure retention of the interests, are being protected. In addition to the standard Management Effectiveness Evaluation systems recommended by IUCN WCPA (Hockings et al., 2006), some additional measures relating to site and process integrity are required specifically for geoheritage sites (Table 4, overleaf).

ENDNOTES

[1] To apply for individual membership of the WCPA Geoheritage Specialist Group contact the Secretary General, Wesley Hill, whill@geosociety.org

[2] See: www.iucn.org/about/work/programmes/gpap_home/

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RESUMEN

El reconocimiento formal del componente de geodiversidad de las áreas protegidas se dio en 2008 en las Directrices revisadas de la UICN para la aplicación de las categorías de manejo de las áreas protegidas. Este artículo defiende la importancia de esta adición y demuestra la necesidad de la conservación del patrimonio geológico en las áreas protegidas, tanto por derecho propio como por su valor más amplio en el apoyo a la biodiversidad y los servicios de los ecosistemas. El artículo resume algunas de las cuestiones claves que los administradores de áreas protegidas habrán de abordar para garantizar que la geoconservación se refleje adecuadamente en el desarrollo y la gestión de áreas protegidas. Se ofrece orientación preliminar sobre el desarrollo de la geoconservación en las áreas protegidas y la pertinencia de las seis categorías de manejo.

RESUME