GEODIVERSITY & GEOCONSERVATION

GUEST EDITOR: VINCENT L. SANTUCCI

Geodiversity and Geoconservation: What, Why, and How?

Murray Gray

Introduction

JUST 100 MILES NORTH OF PHILADELPHIA, the location of the 2005 George Wright Society conference, and straddling Interstate Highway 476, the Northeast Extension of the Pennsylvania Turnpike, lies Hickory Run State Park. Through this protected area runs the outer limit of the last ice-sheet to flow southwards into the USA about 20,000 years ago. As a result, the park displays two very different landscape types that in turn have produced two distinctive sets of wildlife habitat.

The undulating nature of the western part of the park reflects the glacial deposition associated with the end moraine of the ice-sheet and the valley erosion associated with glacial meltwater rivers. The eastern part of the park is higher and was not covered by the ice, but was affected by periglacial processes. These included the frost disturbance of rock outcrops, the frost weathering of boulders, and the downslope movement of these boulders to accumulate in the famous Hickory Run Boulder Field, a National Natural Landmark and State Park Natural Area (Figure 1).

On the glaciated western side of the park, the end moraine is dominated by thin and moist soils, evergreen trees, and sphagnum moss bogs. Blackburnian warbler, red-breasted nuthatch, and northern water thrush inhabit this area, and in the spring spotted and Jefferson salamanders and wood frogs flock to the bogs to breed. On the other hand, the unglaciated eastern side of the park is dominated by beech and chestnut oak trees inhabited by the American redstart, red-eyed vireo, and Louisiana water thrush (Commonwealth of Pennsylvania 2004).

Hickory Run State Park therefore illustrates how the geological evolution of a landscape has produced a diversity of landforms and materials that in turn have provided a range of habitats in which biodiversity has evolved. We do not have to think too hard to understand that Hickory Run is only one example of these types of relationships. For example, think of the range of physical habitats within any one of the large Alaskan national parks, such as Denali, Glacier Bay, or Wrangell–St. Elias. And then contrast these glaciated mountain parks with others such as Hawaii Volcanoes,

Figure 1. Hickory Run National Natural Landmark. Note the graffiti on some stones. *Photo courtesy of the author*

Grand Canyon, Carlsbad Caverns, and Death Valley, and add in any national seashore and national river. This issue of *The George Wright Forum* contains papers outlining in detail several other examples illustrating similar physical/biological relationships. From this and other studies across the world, it can be argued that the Earth's biodiversity is largely due to the diversity of the geological world (geodiversity), and that for land management to be fully effective a holistic understanding and approach is necessary.

What is geodiversity?

"Geodiversity" can be defined simply as "the natural range (diversity) of geological (rocks, minerals, fossils), geomorphological (land form, physical processes) and soil features. It includes their assemblages, relationships, properties, interpretations and systems" (Gray 2004:8). The term first appears in articles from Tasmania, Australia, in the mid-1990s (Sharples 1993; Dixon 1995; Kiernan 1996) and it is no coincidence that this immediately followed the adoption by many countries of the U.N. Convention on Biodiversity at the Earth Summit in Rio de Janeiro in 1992. The Tasmanian geoscientists realized that there are many parallels between biological diversity and diversity in the abiotic world. Using the terms "biodiversity" and "geodiversity" helps to indicate that nature consists of two equal components, living and non-living, and which, taken together, could help to promote a more holistic approach to nature conservation than the traditional biocentric focus.

Subsequently, the use of the term "geodiversity" has spread, particularly in Australia, where it is an integral part of the Australian Natural Heritage Charter (Australian Heritage Commission 1996, 2002), in

Scandinavia (Johansson 2000), and in the United Kingdom (Gray 2004), where several local geodiversity action plans (LGAPs) mirror their biological equivalents (LBAPs) and where a report titled *State of Nature—Geodiversity* has been published (English Nature 2005). However, the term has yet to be adopted in the USA.

Geological diversity is illustrated by the 5,000 or so minerals known to exist in the world, some of which are very rare and could easily be lost. These diverse minerals, when combined with other factors, such as crystal or particle size, shape, and structure, create thousands of different named rock types. About a million fossil species have been identified, but probably millions more await discovery. There are 19,000 named soil series in the USA alone (Brady and Weil 2002). Less easily classified are landforms and topography. Some landform names, such as canyons, end moraines, and arches, are used widely, but much of the Earth's surface form does not fall neatly into a named landform category. There are also many commonly used names for physical processes, e.g., coastal erosion, landsliding, and glacial abrasion, but, when examined in detail, these processes become increasingly complex. Given the above brief discussion, the conclusion must be that there is as much geodiversity in the world as biodiversity.

Why should we conserve geodiversity?

Geodiversity ought to be conserved for two reasons. First, geodiversity is valuable and valued in a large number of ways, and second, it is threatened by a huge variety of human activities. It is a measure of a civilized and sophisticated society that it should want to conserve elements of the planet that are both valued and threatened (Gray 2004).

Values. Table 1 gives a summary of over 30 recognizable values of geodiversity with examples where appropriated from protected areas in the USA. These could be referred to as "geosystem services" to indicate equivalence with the common approach of ecosystem services often used to justify wildlife conservation. Many of them are included in the classification of intangible values given by Harmon and Putney (2003) and Harmon (2004), though here we focus specifically on the values of geodiversity.

Intrinsic or *existence values* are those associated with things simply for what they are rather than what they can be used for by humans *(utilitarian values).* There is a large philosophical and ethical discussion on this topic in the literature, and interested readers are referred to, for example, Attfield (1999) and Beckerman and Pasek (2001).

Cultural values may originate from folklore associated with the origin of rock formations or landforms. For example, the columnar jointing of the Devils Tower National Monument in Wyoming is reputed to be the claw marks of a giant grizzly bear trying to reach a group of people on the summit. Cultural values are also associated with links between rock sites and archaeology. Obvious examples here are the Alibates Flint Quarries, Canyon de Chelly, Gila Cliff Dwellings, and Petroglyph National Monuments. Similarly, some geological features may have spiritual value. Examples include the sacred vision quest sites of North American Indians, such as Chief Mountain within Glacier National Park, Montana (Gulliford 2000) or the nearby Writing-on-Stone Provincial Park in Alberta, Canada. Many other present-day societies also feel a strong bond with their physical surround-

Intrinsic Value	1. Intrinsic value	Abiotic nature free of human valuations
Cultural Value	2. Folklore	Devils Tower NM; Sleeping Bear Dunes NL
	3. Archaeological/Historical	Alibates Flint Quarries NM; Petroglyph NM
	4. Spiritual	Chief Mountain, Glacier NP
	5. Sense of Place	John Muir at Yosemite
Aesthetic Value	6. Local Landscapes	Sea views; sound of waves; touch of sand
	7. Geotourism	Grand Canyon NP; Yellowstone, NP
	8. Leisure Activities	Rock climbing; caving; skiing; hiking
	9. Remote Appreciation	Nature in magazines and TV
	10. Voluntary Activities	Footpath construction; mine restoration
	11. Artistic Inspiration	Moran & Jackson at Yellowstone
Economic Value	12. Energy	Coal; oil; gas; peat; uranium
	13. Industrial Minerals	Potash; fluorspar, rock salt; kaolinite
	14. Metallic Minerals	Iron, copper; chromium; zinc; tin; gold
	15. Construction Minerals	Stone, aggregate; limestone; bitumen
	16. Gemstones	Diamond; sapphire; emerald, onyx; agate
	17. Fossils	Tyrannosaurus “Sue”; fossil & mineral shops
	18. Soil	Food production; wine; timber; fiber
Functional Value	19. Platforms	Building and infrastructure on land
	20. Storage & Recycling	Carbon in peat and soil; oil traps; aquifers
	21. Health	Nutrients & minerals; therapeutic landscapes
	22. Burial	Human burial; nuclear waste chambers
	23. Pollution Control	Soil and rock as water filters
	24. Water chemistry	Mineral water; whisky; beer
	25. Soil functions	Agriculture; horticulture; viticulture; forestry
	26. Geosystem functions	Operation of fluvial, coastal, glacial processes
	27. Ecosystem functions	Habitats and biodiversity
Scientific Value	28. Geoscience Research	History of Earth; evolution; geoprocesses
	29. History of Research	Early identification of unconformities, etc.
	30. Environmental Monitoring	Climate change; sea-level change; pollution
	31. Education & Training	Field studies; professional training

Table 1. Summary of geodiversity values with some examples.

ings, allowing local inhabitants to develop a sense of place. John Muir developed a famously strong relationship with Yosemite, and today the parks are "a lifelong source of awe" for many (Pritchard 1995:xvi).

Aesthetic values relate to the valued impact on the senses instilled by many protected areas. John Muir (1901:56) invited us to "climb the mountains and get the good tidings. Nature's peace will flow into you as sunshine flows into trees." Today tourists are drawn to the stunning scenery of Glacier Bay, the grandeur of the Grand Canyon, the geothermal wonders of Yellowstone, or the rock colors of Zion. Geotourism is at least as popular as ecotourism. We also use the physical landscape for recreational activities. Skiing, rock climbing, caving, canyoneering, whitewater rafting, glacier hiking, all require specific landscapes or geological environments. Many valued landscapes have inspired painters, sculptors, poets, and musicians to create important works. Harmon (2004) notes the contribution of the landscape painter Thomas Moran and the photographer William Henry Jackson in bringing the scenic wonders of Yellowstone to the attention of the U.S. Congress and the general public.

Economic values of geodiversity include fuels such as coal, gasoline, and uranium; industrial minerals such as limestone, gypsum, and phosphates; metallic minerals; gemstones; and construction minerals such as building stone, aggregate, sand, clay, and bitumen. Most of these are non-renewable resources and their use and limits ought to be better understood than they are. Oil is an obvious example, leading to debates over the need for oil exploration in Alaska's Arctic National Wildlife Refuge.

Functional values include geosystem services of subsurface rocks as stores of water, oil, and gas; as burial sites for nuclear waste and potentially for carbon dioxide; and as filters for water as it moves downwards to the water table. Soils are vital for agriculture, viticulture, and forestry, and are an important source of minerals vital for health, such as magnesium, zinc, calcium, selenium, and chromium. River channels perform the function of transporting water and sediment from land towards the sea and their capacity is adjusted to stream discharge. Beaches and sand dunes act to protect the coastline and inland low ground from coastal flooding. Many of these physical systems are in dynamic equilibrium and their continued functioning is vital to environmental systems. As outlined in the introduction, the physical environment also plays a huge role in providing diverse environments, habitats, and substrates that create and nurture biological diversity.

Finally, the physical world also provides opportunities for *research and education.* Research has given us a huge amount of knowledge about the history of the planet, the processes that shape it, the way in which climates have changed, and the evolution of life through time. It is important that the physical evidence for further research is conserved and to ensure that further studies and opportunities to train and educate professional geoscientists, university students, schools, and the general public are not lost.

Threats. Butcher and Butcher (1995) included a long discussion on threats to the U.S. national parks. These threats included dams and diversions, water pollution, geothermal drilling, air pollution, noise pollution, urban impacts both within or adjacent to parks, excessive numbers of cars, visitor use impacts, a science shortfall, and an "et cetera" category that included the impact of concession structures and operations, inappropriate recreational activities, and poaching.

These and other threats continue to have an impact of the georesources of the parks. River and coastal engineering works disrupt the operation of natural geomorphological processes. Leaching of polluted agricultural, mine, or sewage water continues to affect a number of parks. The threat of geothermal resource exploitation in Idaho on the Yellowstone system is still a concern. Urban impacts and car numbers have continued to increase and are a serious threat to several parks, as are visitor and recreational pressures, such as rock climbing at Devils Tower National Monument in Wyoming. And unauthorized fossil collecting is a continuing concern (Santucci 1999).

These human impacts may result in loss of, or damage to, important rocks, minerals, or fossils, remodelling of natural topography, loss of access or visibility, interruption of natural processes, pollution, or visual impacts. Figure 1 illustrates the problem of graffiti on the national natural landmark boulder field at Hickory Run.

As touched upon above, the sensitivity and vulnerability of georesources vary. "Sensitivity" refers to how easily features can be damaged. Some features, such as many cave deposits, are highly sensitive and very easily damaged even by merely walking on or touching them (Gray 2004). Others are much more robust with much higher thresholds of energy required to damage or remove them, and some can repair themselves, such as footprints on a beach which are removed by the next high tide. "Vulnerability" refers to the likelihood of damage given public access or lack of it. Obviously the greatest threats are to highly sensitive and vulnerable features and systems.

How should we conserve geodiversity?

Different elements of geodiversity need to be protected and managed in different ways. Table 2 is a possible general scheme. It distinguishes between rare and common occurrences since it is argued that geodiversity, and indeed the environment in general, should be respected both within and beyond protected areas. With these aims in mind we can then consider the detailed approaches required to meet the aims.

Clearly, creating a protected area with the supporting legislation and penalties is one approach but does not guarantee protection due to infringement of regulations or changes in political attitudes or funding. Fines are rarely substantial enough to deter commercial collectors. One of the most secure methods is to physically restrain visitors from reaching sensitive sites by fencing or even by placing them within specially constructed buildings. For example, the remaining easily accessible petrified tree at Yellowstone National Park is surrounded by a high fence to prevent illegal collecting (Figure 2). In other places at Yellowstone, boardwalks and fences encourage visitors not to stray onto delicate formations. At Craters of the Moon National Monument in Idaho, notices inform visitors that they are not permitted to stray from the paths because of the easily cracked lava surface. If we are dealing with rare fossils, minerals, or rocks, an effective means of protecting is burial *in situ* or removal and curation in a museum. This is often the approach taken with dinosaur and other fossils. A third effective way of conserving nature is for a nature conservation charity to buy sites with the remit of retaining them for their nature conservation value in perpetuity. An example is The Nature Conservancy, which owns Egg Mountain in Montana, famous

Category	Occurrence	Geoconservation Management Objective
Rock	Rare	Maintain integrity of outcrop and subcrop. Remove samples for curation.
	Common	Maintain exposure and encourage responsible collecting and curation.
Mineral	Rare	Maintain integrity of outcrop and subcrop. Remove samples for curation.
	Common	Maintain exposure and encourage responsible collecting and curation.
Fossils	Rare	Wherever possible, preserve in situ. Otherwise remove for curation.
	Common	Encourage responsible collecting and curation.
Landforms		Maintain integrity of landforms and restore/encourage authentic contouring.
Landscape		Maintain contribution of topography, rock outcrops and active processes to landscape and restore/encourage authentic contouring.
Processes		Maintain and restore integrity of operation.
Soils		Maintain soil quality, quantity and function.
Other georesources		Encourage sustainable use, and value that use in historic and modern contexts

Table 2. Geoconservation aims for the eight elements of geodiversity.

for its Maiasaur dinosaur finds (Horner and Dobb 1997).

Education has an important role to play in helping to conserve features. At Devils Tower National Monument, a climbing management plan has been introduced to monitor climbing impacts, educate climbers, retain rock faces that are currently free of bolts, and investigate whether some bolt holes can be repaired. Interpretation boards, leaflets, and trails can carry educational messages about nature conservation interests and the correct behavior in conserving them, as can ranger-led talks and walks.

Part of conservation should also include adequate scientific documentation about the geological interest of protected areas, promotion of further research as necessary, and a conservation management plan that is regularly updated. The latter should include a program for monitoring the con-

Figure 2. Fencing to protect a remaining petrified tree at Yellowstone National Park. *Photo courtesy of the author*

dition of geoheritage assets within the protected area and an enhancement and restoration program to upgrade facilities and repair damage. The U.S. National Park Service's abandoned mineral lands program is an example of the latter, and successful land restoration schemes have been carried out at Redwood and Joshua Tree National Parks in California. Land management in general should aim to retain the integrity of landforms, landscapes, and active processes, and restore them authentically where possible.

Conclusions

Geoconservation should be driven by the need to conserve geodiversity, given its value and the real and potential threats to it. Without geodiversity there would be little biodiversity, and an integrated approach to nature conservation and sustainable land management ought to be obvious. Too many nature conservation organizations and objectives are riddled with institutional biocentrism. But geoconservation is at last being taken more seriously because it is impossible to have a sensible land management strategy that ignores the physical aspects of the environment, e.g., topography, soils, and physical processes. The concept of geodiversity provides a fundamental basis for geoconservation and deserves to be more widely adopted in North America. I hope this volume of *The George Wright Forum* helps to stimulate interest in and debate on these new ideas.

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Murray Gray, Department of Geography, Queen Mary, University of London, Mile End Road, London E1 4NS, United Kingdom; j.m.gray@qmul.ac.uk