

# Geology and biodiversity- making the links

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Peter Wakely/English Nature 14,727  
Main: Cornwall rock. Michael Murphy/English Nature



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Dunstanburgh Castle, Northumberland. Anna Wetherell

The landscapes of England are hugely varied. There are the lakes and mountains of Cumbria, the rugged spine of the Pennines, the limestone dales of the Peak District and Yorkshire, the rolling chalk downs of Wiltshire and the Chilterns, and the flat expanses of the Fens. The coastline ranges from the rocky shores of Devon and Cornwall to the vast expanses of mudflats and saltmarsh within our estuaries.

These landscapes hold a diversity of habitats and species, special throughout Europe. We have woodlands and heathlands, chalk grassland, rivers, fens and bogs. But why do we have such variety in such a small space? The answer lies in the diversity of the underlying geology.

For all living organisms, including humans, our environment affects the way we can live and the resources available to us. This environment is fundamentally a result of **climate** (rainfall, light and temperature), the **physical landscape** (slope, aspect and altitude), and **substrate**. The combination of these factors, plus the interactions of the **living organisms** present in that environment, is the **ecosystem**.

Geology is a critical factor. It influences climate at global, regional and local scales. Landscape is determined by the nature of the rocks that lie beneath the surface and the processes that have shaped and formed them. Substrate and soil are closely related to the nature of the rocks from which they are derived.

When working with ecosystems, we need to take a holistic approach in understanding the geology, the wildlife and how they interact to shape the ecosystem.

## Past ecosystems

Since the Earth was formed 4,600 million years ago it has never stood still. Plate tectonics (the movement of the Earth's crust) has brought continents together and pulled them apart. This has continuously changed the pattern of land, ocean and climate and has also driven evolution, extinction and an ever-changing pattern of ecosystems.

Britain vividly illustrates this dynamic Earth. Our oldest rocks are 2,800 million years old. Since the Cambrian (approximately 500 million years ago), plate movement has carried Britain from 30 degrees south of the equator to its present position. Britain's rocks record the vast changes of climate and environment as Britain has changed from land to sea, and from tropical to temperate to glacial.

## Carboniferous (354-290 million years ago)

Carboniferous rocks are a record of equatorial environments and changing sea levels. Initially, under a warm, tropical sea extensive reefs of crinoids and corals developed. As the sea level dropped, rivers brought in sands and silts from the land areas, forming vast sandy deltas. On top of the deltas thick swamp vegetation developed, including trees, ferns and horsetails.

Today the Carboniferous rocks show this change. The early tropical limestones outcrop widely, forming the Mendip Hills, the Avon Gorge, the Derbyshire

Peak District and the Yorkshire Dales. Thick deltaic and riverine sandstone forms the overlying Millstone Grit in the Midlands and northern England, whilst the swampy vegetation was compressed to form the coal seams of the adjacent, low-lying Upper Carboniferous Coal Measures.

Just as importantly, this range of rocks provides a substrate for a range of habitats. The Carboniferous limestones of the Peak District, Yorkshire Dales and the Mendips support limestone grasslands and form a network of karst and caves, and the Millstone Grit underlies the moorlands of the Pennines.



Crinoid fossils, Salthill and Bellmanpark Quarry SSSI, Clitheroe, Lancashire. Peter Wakely/English Nature 7,317



Peak Cavern and Peveril Castle, Castleton, Derbyshire. Anna Wetherell





**Permian and Triassic  
(290-205 million years ago)**

Hot, arid desert conditions dominated the Permian and Triassic. Extensive red sandstones and mudstones were deposited, which now form the characteristic red rocks of the south coast between Exmouth and Sidmouth, the low-lying ground and linear ridges of the Cheshire Plains and the red sandstone cliffs of St Bees Head in Cumbria. Shallow seas existed in north east England during the Permian, containing limestone reefs which now form the north-south Magnesian Limestone escarpment. The evaporation of the seawater changed the limestone to dolomite, making it rich in magnesium rather than calcium.

Now the sandstones provide an opportunity for heathland to flourish in Cheshire and the Wirral, and underlie the rich pastures of Cheshire and Warwickshire. Magnesian limestone grassland occurs only where the Permian evaporating seas once were.

Left: St Bees Head, Cumbria. Peter Wakely/English Nature 21,304

Magnesian limestone, Cassop Vale NNR, Durham. Peter Wakely/English Nature 21,224



Valley of Stones NNR, Dorset. Peter Wakely/English Nature 21,939

**Quaternary  
(1.8 million years ago to present)**

The most recent major climatic change has been the last Ice Age. Around 2.5 million years ago, the Earth became colder and ice expanded from the poles. Northern Europe experienced rapid changes in climate. There were significant, cyclic fluctuations between colder temperatures when the ice advanced (glacials), and a warmer, more temperate climate (interglacials). Much of Britain was periodically covered with glaciers and, beyond the ice, tundra and permafrost.

The ice scraped off any soil which had developed, leaving sculpted bare rock, or depositing clays, sands and gravels in its place in glacial landforms. What soil was left blew around the frozen landscape, forming deposits known as loess. Rivers carried glacial meltwaters, depositing massive amounts of sediment in the sea and on land. River courses developed and changed as ice advanced and retreated leaving complex river terraces. As sea levels rose and fell, coastlines moved back and forth.

The major expanse of ice meant that sea levels dropped and Britain was connected to mainland Europe. Woolly mammoth and woolly rhino lived here, along with hyena, deer and bears. Man also arrived. Changing climates, the gradual recolonisation by plants, the changing fauna, and the impacts of man, are all shown in pollen and sediment records, often found in peat bogs or lakes. A major impact of the ice was that much of Britain was literally 'scraped clean'. The landscape and environment we know today has really only evolved over the last 10,000 years or so.

Many of these ancient ecosystems sound familiar from environments today, and indeed geological interpretation develops from understanding modern-day ecosystems. Geology is strongly rooted in both the present and the past. We can learn much from the past for the future, especially about the impacts of climate change. The rock record shows that changes in climate occur not only as a result of the movement of continents around the planet, for example Britain's progress northwards, but

also from changes in atmospheric composition, the circulation of ocean currents and the rise and fall of sea level. Geology teaches us just how interlinked and interdependent the environment and ecosystems are on Earth.

Understanding this interdependence is essential to understanding how and why our environment is changing. Our environment has changed in the past and is continuing to change. Ecosystems react to this and provide a feedback loop into it. In this present period of climate change, part driven by our own interaction with our environment, such knowledge can guide us how to work within this.



Woolly rhino skeleton found at Whitemoor Haye, Alrewas, Staffordshire. Field Archeology Unit, Birmingham University





Derwent Water, Lake District, Cumbria. Paul Glendell/English Nature 23,075A

### Present-day ecosystems

Ecosystems result from the interaction of climate, physical landscape, substrate and living organisms. They develop at various scales. The planet can be regarded as an ecosystem, as can a woodland, a peat bog or a rock pool.

Rocks determine landscape in a number of ways. Harder rocks erode less easily than softer ones, leaving the harder rocks standing out in the landscape. The processes of plate tectonics can fold rocks. This process has led, for example, to the pattern of landscape seen in the Weald and the spectacular landscape of the Lake District. Weathering and erosion shape the rocks, whether due to wind, rain or ice. The mountains of Scotland would have once stood as high as the Alps, but millions of years of erosion have softened the landscape considerably.

Variations in landscape affect climate and weather. On a global scale, the distribution of land and ocean, and the changing height of the land, controls the way air circulates around the planet. This

is a key influence on global climate. At a local scale, the geology can affect regional weather patterns. For example, the Pennine ridge that runs through England forces air to rise over it, which causes water to condense, form clouds and fall as rain. As a result, the north west of England is generally wetter than the east, which broadly influences the development of ecosystems. Most of our peat bogs occur in the north west because of this difference in climate.

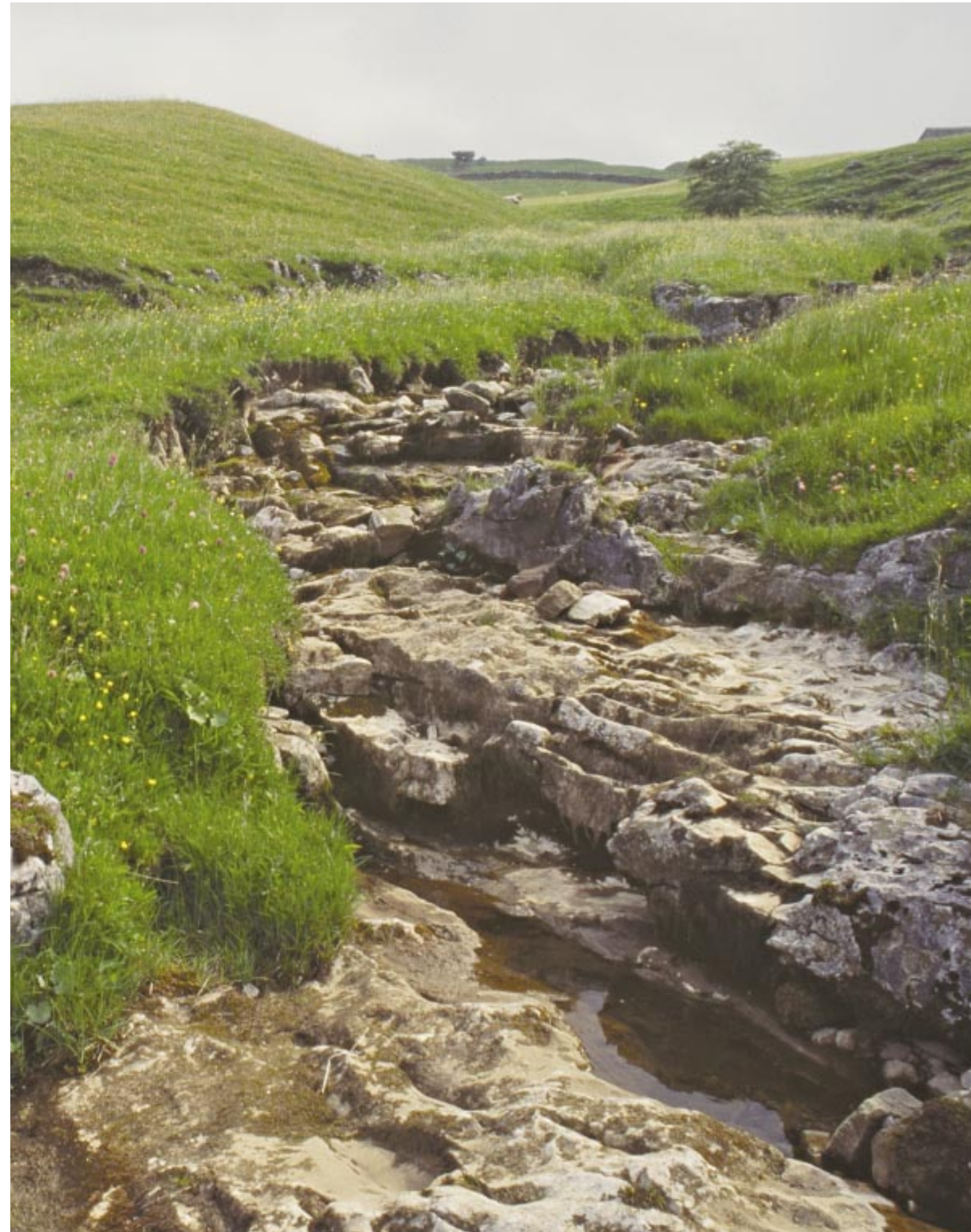


Fens under snow near Holme Fen NNR, Cambridgeshire. Peter Wakely/English Nature 11,342

Substrate is also fundamental to an ecosystem and comprises the underlying rock or soil, in which the plants grow. In terrestrial ecosystems, the plants are the foundation of the food chain. Substrate is therefore the foundation of life.

Soil derives from rock. As rock breaks down through weathering and erosion, the resulting particles form the basis for soil. Soil evolves as a result of physical and chemical processes, and biological activity. It can vary from a very thin cover, or none, to deep soils and peat. The source material is important in determining the chemical and physical nature of the developing soil. Chalks and limestones lead to an alkaline, usually well-drained soil; sandstones, sands and gravels lead to an acidic, well-drained soil; while finely-grained rocks, such as clays, mudstones and shales, can lead to a poorly-drained soil.

These variations in substrate are the foundation for the diversity of habitats and species that have developed in England. They reflect the diverse geology, geomorphology and resultant landscape that we see around us.



Deepdale Meadows SSSI, North Yorkshire. Peter Wakely/English Nature 19,667





Mole Gap SSSI with regenerated escarpment, Surrey. Herb rich National Trust grassland. Peter Wakely/English Nature 21,305

## Chalk

During the Upper Cretaceous (95-65 million years ago) an extensive, shallow sea covered much of Britain and deposited a thick, pure limestone known as chalk. The chalk today characterises the rolling hills of the South and North Downs, the Chilterns and the Lincolnshire and Yorkshire Wolds, and supports a characteristic calcareous flora.

A number of features of the rock, including porosity and softness, influence chalk landscapes and their ecosystems. High porosity produces a flora dominated by perennials with relatively deep root systems and low-growing plants specifically adapted to calcareous, arid and nutrient deficient conditions (eg autumn gentian *Gentianella amarella* and the hairy violet *Viola hirta*). Beech *Fagus sylvatica* woodland is also intimately (though not exclusively) associated with chalk. Well-known sites include the beech woods of the Chilterns, east Hampshire and the North Downs.

In detail, the woodland community changes as slopes become steeper, from relatively deep, moist and base-rich soils to the thin, dry and strongly base-rich soils of steep slopes.

In England the silver spotted skipper butterfly *Hesperia comma*

is restricted to the chalk, breeding in open chalk grassland. Its food plant, sheep's-fescue *Festuca ovina*, is widely distributed. However, only south-facing (and grazed) chalk slopes provide the warm microclimate and short turf needed for its larvae and pupae to develop.

Hairy violet *Viola hirta*, Surrey. Peter Wakely/English Nature 18,828



## Serpentine

Serpentine broadly describes rocks, minerals and soil associated with metamorphosed ultramafic (low silicate content) rocks containing serpentine-group minerals. Soils derived from serpentine-rich rocks are high in iron and magnesium, low in calcium, phosphorus, potassium and molybdenum. They may also be high in nickel, chromium, manganese and cobalt and can produce a range of soil types which vary according to parent rock, weathering, relief and biological processes.

In Britain, serpentinised rocks are uncommon. One of the best known outcrops is the serpentinised peridotite of The Lizard ophiolite in south west Cornwall, which was part of the oceanic crust in mid-Devonian times (around 375 million years ago).

Much of The Lizard is underlain by serpentinite and the vegetation is broadly described as heathland. Plants are typical of dry acid heath but include the rare Cornish heath, which is the most abundant heather here. What is unusual is the presence of typical chalk- or lime-loving species including common dropwort *Filipendula vulgaris* and bloody crane's-bill *Geranium sanguineum*. This relationship is not understood in detail but it is possible that some species found on The Lizard may have evolved local adaptations to the unusual conditions associated with the complex geology of the peninsula. The occurrence inland of typically coastal species (for example thrift *Armeria maritima* and sea campion *Silene uniflora*) also reflects the chemical similarities between seawater and serpentine soils.



Erica vagans, Ulex gallii, Goonhilly Downs SSSI. The Lizard NNR. Peter Wakely/English Nature 10,798



Predannock Downs, The Lizard NNR, Cornwall. Peter Wakely/English Nature 15,803





Sugar limestone on Widdybank Fell. Moor House - Upper Teesdale NNR, County Durham. Peter Wakely/English Nature 14,155

### Sugar limestone

Found in Upper Teesdale, County Durham, the 'sugar limestone' is a thin bed of limestone that was metamorphosed into a coarsely crystalline marble by the intrusion of the Whin Sill dolerite. The rock weathers extremely slowly into a thin, drought-prone soil, with a grain size similar to granulated sugar.

The sugar limestone supports a species-rich grassland dominated by blue moor-grass *Sesleria*

*albicans* and includes two sub-communities found only in Upper Teesdale. It supports one of the richest groups of rare species in Britain including spring gentian *Gentiana verna* and Teesdale pansy *Viola rupestris*. Some of the more unusual plant communities occur where streams (or 'sikes') have weathered the limestone to hard crusts and unstable gravels which in places produce moss hummocks. This is the only place in Britain where Teesdale sandwort *Minuartia stricta* grows.

At all scales, differences in geology and landscape lead to variations in climate. In turn this influences global weather patterns, regional rain patterns and microclimate. For example, north-facing slopes tend to receive less sunlight and warmth. Similar variations influence soil type and lead to differences within habitats. All this combines to create mosaics of habitats, opportunities for a diverse range of plant and animal species and the complex range of ecosystems we see around us today.

Man's influence is a significant additional influence on ecosystems in England. Land management, for example in the form of agriculture, grazing and woodland management, have all had significant impacts on the diversity of habitats and species found here. Heathlands and grasslands are unlikely to survive without management, as they often develop naturally into scrub and woodland. Our demands for water have a significant impact on hydrological systems, and thus the water available within ecosystems. The development of industry has increased levels of pollution in the air, water and on land, and the availability of artificial fertilisers and pesticides.

None of this is static. As the Earth has changed over millions of years so the landscape around us continues to evolve. Geomorphological processes continue to act on our landscape through weathering, land movements, rivers and coastal processes, even sometimes earthquakes. Working with ecosystems involves appreciating the diversity of nature, but also accepting change. We may have a significant influence, but ultimately we cannot control natural processes. We are also facing global climate change, largely induced by our own activities.



Millstone Grit 'sculpture' near Hathersage in the Peak District. Paul Glendell/English Nature 24,063

### Future ecosystems

The UK has set itself challenging targets for maintaining and restoring habitats and species across the UK through the UK Biodiversity Action Plan (UKBAP). Government also has targets relating to the condition of Sites of Special Scientific Interest. Can we use the links between biodiversity and geodiversity to achieve these targets and help with understanding ecosystems? Within the nature conservation field it often appears that geology and biology are two completely different subjects. However, bringing the two together has practical benefits.

The links between geology and biology can be used as a management tool, as a way of designing surveys, or as an analytical method. We can map changes in the geology or soil type

along with the vegetation. Changes in substrate, or in hydrology can answer questions about the distribution of habitats and species. When considering management techniques, particularly when relating to altering practices, taking geology, substrate and hydrology into account can predict results more accurately.

For species with well-known requirements, links with substrate and hydrology can be a useful tool for focusing surveys where the distribution is uncertain. Geological maps exist at a range of scales, covering both solid (pre-Quaternary) and drift (Quaternary/recent) deposits. Along with soil maps, when these are combined with detailed knowledge of potential habitat and species requirements, they can provide an excellent tool for planning survey and management.

### Searching for the shore dock

Shore dock *Rumex rupestris* is a scarce plant found generally in the south west, on beaches where sediments known as 'head' or 'till' meet the beach, often with a flush or seepage. Using this knowledge and geological maps, possible new sites were identified. Designing the next season's survey took these possible locations into account, with great success. As a result, the known population of shore dock in the south west increased by 30%. This method can be used widely, to identify suitable habitats for survey, for relocation or for re-creation of a range of potential habitats and species.

Shore dock *Rumex rupestris*, Cornwall. Peter Wakely/English Nature 18,105





## Managing geodiversity and biodiversity together

Geological sites are important for their biodiversity. There are very specific relationships, such as the strong link between exposed rock surfaces and lichens, or between rare metallophyte plants and mine dump spoil. There are also other broad relationships, such as the benefit that bare ground and rock surfaces bring to a range of invertebrates or simply as nesting sites for birds.

reflected in the number of disused quarries identified as important for their biodiversity.

It is important that a wider view of 'site management' is taken. When establishing management plans for geological sites it is important to incorporate the biodiversity gain that can be achieved. Equally, management of biological sites should consider the potential benefits for geology. The principle is simple, and can bring wide benefits.



Sand martin nests in disused sand and gravel pit. Michael Murphy/English Nature



Lichens on sarsen, Fyfield Down NNR, Wiltshire. Peter Wakely/English Nature 11,633

Importantly, the management of geological sites benefits biodiversity. In coastal and river environments the best geological management is to maintain natural processes. This non-intervention should maintain a natural habitat succession. Inland, typical management of geological sites involves removing or redistributing scree and clearing vegetation to provide a mix of bare rock, open ground and habitat mosaic.

There is, however, a poor understanding of the biodiversity of geological sites or the geodiversity of biological sites. Nevertheless, it is clear that disused quarries, for example, offer a refuge and diversity of habitat for both specialist and non-specialist species. This is



Rock face, Hulme Quarry NNR, Staffordshire. Paul Glendell/English Nature 25,999



Tufa dams, Slade Brook, Gloucestershire. Roger Meade/English Nature

## Water management – understanding geology to manage biology

When managing wetland sites, both permanent and ephemeral, understanding the catchment dynamics and the interaction between groundwater, bedrock and superficial deposits is extremely important.

Water alkalinity is a key aspect influencing the biology of rivers and streams. Understanding the geology and geomorphology of a watershed can help to predict alkalinity. Watersheds with granitic bedrock have low alkalinity, whilst those with calcareous sedimentary bedrocks have high alkalinity. The chemistry of extensive river systems, such as the River Tweed in northern England and Scotland, changes as the underlying geology changes. The plants and animals living in the river will vary according to the different environmental conditions.

Base-rich lakes and water bodies are usually confined to calcareous

environments, which are normally free-draining – so standing water is rare here. The Jurassic Oxford Clay, however, is relatively calcareous and brick pits, such as Orton Pit near Peterborough, can provide extensive alkaline pond systems. The Orton Pit supports ten charophyte (stonewort) species including the main English population of the bearded stonewort *Chara canescens*. This early coloniser of ponds prefers slightly brackish conditions which are produced by the release of salts contained within the Oxford Clay. This site also holds a large

population of great crested newts *Triturus cristatus*.

Karst (limestone surface features) and caves have a specific hydrology, where water mainly flows underground. Complex links exist between areas of drainage and re-emergence. Streams flowing out of limestone systems are usually saturated in calcium carbonate, creating specialised habitats such as tufa springs. Caves themselves provide an additional habitat important for a range of species, including bats.

Tufa deposits, Slade Brook, Gloucestershire. Roger Meade/English Nature





There are many opportunities to use this holistic approach. English Nature developed the framework of Natural Areas, which link to the Character Areas developed by the Countryside Commission (now Countryside Agency). These look at landscape-scale characteristics of geology and habitats, and can be used to develop broad objectives for biodiversity and to identify regional issues. Natural Areas are useful for identifying which areas are important for which habitats and species, and are, unsurprisingly, closely linked to the underlying geology.

Bringing together several layers of data can help to identify patterns and make links between geology, biodiversity and landscape. Landscape-scale projects can help to protect individual sites, such as SSSIs, by providing buffer zones for sensitive habitats. Peatlands, for example, will often need careful water level management of the surrounding land to ensure that water levels are maintained within the site. Species can also benefit from landscape-scale projects, through corridors and pathways which allow populations to expand and move around. BAP

targets can only be met by understanding the ecosystems which support the individual habitats and species.

Geological maps, soil maps and distribution of vegetation are all useful tools in working with ecosystems. Now we have a strong series of specialist bases, we need to learn to bring those specialisms together, to achieve the goals of conserving both biodiversity and geodiversity.

## Key messages

- England's geology is extremely diverse. It illustrates a continuously changing past over hundreds of millions of years. Changing climate, evolving life, rising and falling sea, mountain building, earthquakes and volcanoes are all part of this geological history.
- Geology directly influences the character of our landscape, habitats and species. This diverse and dynamic geological past has produced the diversity of landscape we see around us. There is a direct relationship between geodiversity and biodiversity.
- Geology influences climate. The global pattern of continents, a consequence of plate tectonics, influences global weather, mountain chains affect regional weather patterns and aspect can determine microclimate.
- Geology directly influences substrate. Soil is derived from underlying parent rock and directly reflects the physical nature and chemistry of local and regional geology.
- Geology is crucial to the way ecosystems function. Ecosystems result from the interaction of climate, physical landscape, substrate and living organisms. Geology influences all these factors.
- To fully understand ecosystems and better manage our environment it is essential that we integrate the way we work and think. We must bring together our understanding of geodiversity and biodiversity.
- Geology tells us how our environment has changed and reacted to change. It is important to understand this to better prepare for future change.
- Bringing geodiversity and biodiversity together can help us better understand the environment around us and how to work with this changing environment.
- Managing geodiversity and biodiversity together is mutually beneficial. Many geological places are important for biodiversity and many places important for their habitats and species have geological value.

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