ENGLISH NATURE

Rural Development Service

The Countryside Agency
Landscape Access Recreation

Natural foundations: geodiversity for people, places and nature

working towards *Natural England*
for people, places and nature

Contents

Hartland Quay, Devon. Peter Wakely/English Nature 20,326A

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Foreword

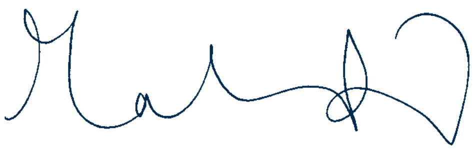
England is renowned for the diversity and historic significance of its geology. The geodiversity this creates is the foundation of England's character. Geodiversity (rocks, fossils and minerals, landforms and landscapes, geological processes and soils) is a valuable environmental asset but it is one of the least recognised and valued. It links rocks to soils, landscapes and habitats, extends from the coast up to the mountains and follows streams down to the oceans. It transcends all administrative boundaries, encompasses rural and urban settings and links the past to the present and the future.

This report on geodiversity is the fourth in a series, following English Nature's previous *State of Nature* reports on the uplands (English Nature 2001), maritime environment (Covey & Laffoley 2002) and lowlands (Townshend, Stace & Radley 2004). *Natural foundations: geodiversity for people, places and nature*, however, has been written as part of the confederation process towards *Natural England* and reflects the shared views of English Nature, the Countryside Agency and the Rural Development Service.

Natural foundations examines geodiversity, its environmental importance and its influence on the way we live. Geodiversity plays a fundamental role in contributing to sustainable development. It underpins our economy directly, through exploitation of resources, and indirectly through activities such as tourism and recreation. It encapsulates scientific evidence allowing us to unravel past events and to understand and predict future changes such as the effects of global warming. Geodiversity has a crucial role in providing a number of environmental benefits from absorbing pollution, buffering climate change and controlling the flow of water. It also provides an inspirational backdrop to our lives, inspiring art, music and culture as well as providing the landscape setting for active and informal recreation and enjoyment of our surroundings.

Importantly, this report demonstrates how wide the influence of geodiversity is on our natural environment and landscape and explores the necessity and challenge of better understanding and using this cross-cutting resource across a range of environmental fields. This report is aimed at a broad range of environmental practitioners and sets out priorities for the better conservation, management and enhancement of geodiversity.

To meet this challenge will require innovative thinking, new methods of working and the use of every opportunity to promote an integrated approach to environmental conservation, management and enhancement. *Natural foundations: geodiversity for people, places and nature* is an important step towards this integration and *Natural England* provides the opportunity to establish and promote this cross-cutting approach to our natural environment and landscapes that links 'people, places and nature'.



Sir Martin Doughty
Chair Designate, *Natural England*

Rocks at Porthleven, Cornwall. Mick Murphy/English Nature

Executive summary

Geology is the bedrock of our environment. The look of our diverse landscapes, and the ways in which we use them are determined by the variety of rocks, minerals, landforms and soils that underlies them. Collectively we refer to the various elements of geology – and the natural processes that shape them – as geodiversity.


Pat Sargeant

Variscan folds, Porthleven Cliffs, Cornwall.

Introduction

England has some of the most diverse geology in the world – a sequence of rocks that includes every major period of geological history for the last 700 million years. This diversity, and the distinctive landscapes it has helped create, has been central to the development of geological science and is an important factor in England's economic wealth and cultural identity.

England's geodiversity is a vital resource and, although we can conserve some of it in protected areas such as SSSIs, Regionally Important Geological and geomorphological Sites (RIGS) and National Parks, the accelerating pace of development is putting great pressure on our geology, landscapes, soils and minerals. Failure to conserve and manage these resources will have increasingly serious environmental, economic and social consequences.

People – influencing what we do

Geodiversity has always had a strong influence on our lives. We have built our castles on hills and rocky outcrops, large trading centres have flourished by navigable rivers and natural harbours, and villages have taken root in sheltered valleys, near natural springs and on tracts of fertile soil.

Field landscape near Holme Fen, Cambridgeshire.


Mick Murphy/English Nature

Paul Glendell/English Nature 23,079A

Derwent Water and Skiddaw, Lake District.

Much of our industry depends on geodiversity. The quality and range of our soils have largely determined where we can grow crops and graze our livestock, while England's mineral wealth has done much to contribute to our prosperity. Ores, such as tin and copper, have been mined here for thousands of years and, more recently, the Industrial Revolution was fired and fed on the coal and iron of the West Midlands and the North East.

Today, tourism is an important industry, and much of it depends on the diversity of our landscapes. The Peak District, Dorset coast, South Downs and picturesque villages of Suffolk are all tourist destinations defined by geodiversity – directly in the case of Dorset where the sea constantly works to erode spectacular and fossil-rich cliffs; or indirectly in the case of Suffolk where the distinctive local building style is characterised by the use of flint.

Places – defining where we live

A combination of diverse rock-types, landforms and soils, together with natural processes such as past glaciation and river erosion have helped form our distinctive local landscapes; from the chalk hills of the Chilterns, to the limestone uplands of the Yorkshire Dales and from the dramatic tors of Dartmoor to the wide mudflats of The Wash. This diverse geology also determines the distribution and range of England's natural habitats because it influences what types of plants and animals an area can support. It is, in short, a fundamental part of our natural environment.

Although the importance of geodiversity in the environment is obvious when looking at an iconic landscape such as the White Cliffs of Dover, in other areas, such as the fens of East Anglia, this fundamental connection is often ignored. We have to remind ourselves that every English landscape – whether mountainous, hilly or flat – owes its character to geodiversity.

In many places the most obvious indication of the underlying geology is the choice of local building stones. In the Cotswolds a traditional cottage will be built with honey-coloured limestone, while in the Lake District the villages are characterised by slates ranging in colour from green to dark grey. In both cases local materials have combined with the distinctive landscapes they helped shape to create a strong sense 'of place' – unique vistas that have provided an inspiration to writers, poets, musicians and artists throughout the centuries.

Mick Murphy/English Nature

Landscape with dry-stone walls, Litton, Derbyshire.

Nature – achieving a balance

The diversity of our rocks, fossils and minerals has been central to England's pioneering role in the sciences of geology and geomorphology. Today, a growing understanding of our geological past is being used to help predict changes in our environment, offering, for example, insights into climate change and how it will affect our lives. As we increase our understanding of the role that geodiversity plays within the wider environment, and its influence on our wildlife, we can help ensure a positive future for species and their habitats as they respond to a changing world.

A better understanding of geodiversity will also be crucial if we are to reach our goal of sustainable development. Many of the processes that created England's mineral wealth, landscapes and soils operate over millions of years and these resources cannot be renewed within a human timeframe, if at all. For this reason the use of non-renewable mineral deposits, fossil fuels and building materials – and the search for alternatives – must be carefully managed. Scientific research will help us find the most effective ways to do this.

As well as guiding the future of industry, research can also help reduce the damage to geodiversity caused by activities such as agriculture and forestry. For example, bad agricultural practices can lead to the destruction and degradation of soils, while poorly planned tree plantations can obscure or destroy the geological value and character of our landscape. Badly managed tourism and recreation can also be detrimental to geodiversity, particularly in sensitive upland landscapes where damage and erosion from over-use can be serious, persistent and slow to heal.

Another threat to geodiversity, and perhaps the greatest, is inappropriate development planning. New developments often destroy or conceal valuable geological exposures and disrupt the natural processes that helped form them. The best illustrations of this are poorly planned coastal developments that prevent natural coastal change, and badly managed river systems responsible for increased erosion and flooding.

Acting together

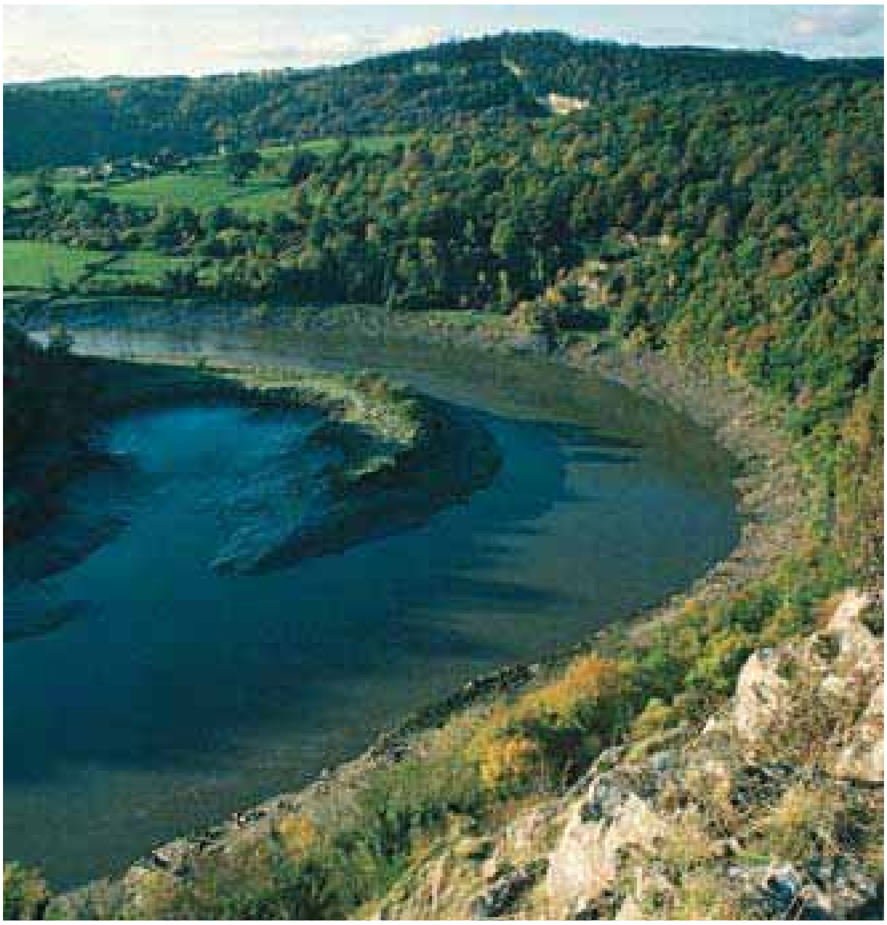
We must ensure a sustainable future for England's geology, landscapes, landforms and soils and the natural processes that helped form them. Traditionally, the conservation of geodiversity has focused on individual sites but, in the future, effective conservation will need to integrate the efforts of all interested parties and seek to conserve geodiversity in the wider landscape.

To achieve this, geodiversity must be considered at every stage of the planning and development process, and at all scales (local, regional and national) following clear policy guidelines on the best ways to conserve it. When any development – large or small – is proposed we must assess its potential impacts on geodiversity, take steps to mitigate any damage that cannot be prevented, and identify opportunities that might benefit geodiversity. For example, some developments might allow the creation of more rock exposures, or offer an opportunity to re-establish natural systems; in others, planning permission may insist on mitigation, such as future monitoring and maintenance work.

Strategic initiatives, such as Local Geodiversity Action Plans (LGAPs), should be established across the country. Usually based on a county or similar area, LGAPs provide a long-term framework for the conservation of geodiversity. The plan takes into account both local and national needs and involves a wide range of partners, from local community bodies and conservation organisations, to local government and industry.

As well as monitoring individual developments, we must also look at them collectively in the landscape to ensure they do not undermine what is valued in the wider environment. For example, there is little point in sensitively managing a new quarry development if the transport infrastructure it requires cuts across huge swathes of valued landscape. A valuable tool in this monitoring process is Landscape Character Assessment, a way of describing and assessing existing landscapes and their geodiversity. This process can help influence planning decisions by assessing a landscape's sensitivity to change and determining how far it can be altered without transforming or destroying the features that make it unique.

River Wye, Gloucestershire.



Peter Wakely/English Nature 9,336

Mick Murphy/English Nature

South Downs, West Sussex.

As well as Landscape Character Assessment, other monitoring initiatives, such as 'Countryside Quality Counts,' are being used to understand the broad trends in countryside change and the likely impacts of that change. By providing valuable information to planners and the public, these monitoring tools can be used to help us strike a balance between nationally accepted 'best practice' and the needs of local communities. An additional benefit is that they work across administrative boundaries and help influence development planning and land management on sub-regional and regional scales.

Conclusion

England's geodiversity is the bedrock of our environment, it is the source of much of our wealth, an important factor in our cultural identity, and will play a vital role in our future development. Geodiversity is fundamental to virtually everything we do, but it is often taken for granted or ignored. For this reason we must raise awareness with planners and the public alike of the importance of geodiversity and its fundamental role in the shaping of our environment.

Because geodiversity is so vital to our existence we must increase our understanding of the processes that form it and those that can damage it. In the short term, this knowledge will help us conserve England's wildlife and manage our non-renewable resources more effectively. In the long term it will help us understand, predict and prepare for the effects of broader environmental trends, such as climate change and rising sea levels.

In the past we have successfully conserved many geologically important sites on an individual basis, but in the future we must work together with others to conserve geodiversity in the wider landscape not just as isolated pockets. Although it is not easy to develop a coherent, integrated approach to the protection of geodiversity, there are now many examples of good conservation practice to follow, and the rewards of co-operation – arriving at better solutions for the environment while meeting social and economic objectives – are clear.

Geodiversity for people, places and nature

Geodiversity directly influences our natural environment, our landscape and where and how we live. Decisions affecting geodiversity are critical to the quality of our lives and environment.

People: influencing what we do
We are irrevocably linked to geodiversity. It influences where we live, provides the raw materials for building and the resources we need for economic growth and survival. It influences our cultural life and wellbeing and is at the heart of the way we live. Geodiversity must be promoted as an integral part of our heritage and culture, and as a vital resource for education and learning. We must understand that, once damaged, removed or destroyed, many aspects of geodiversity are irreplaceable.

Places: defining where we live
Geodiversity underlies the distribution and character of soils, habitats and species and the character of our built environment. It cross-cuts natural and man-made environments and is essential to achieving the ecological, social and economic goals of sustainable development.

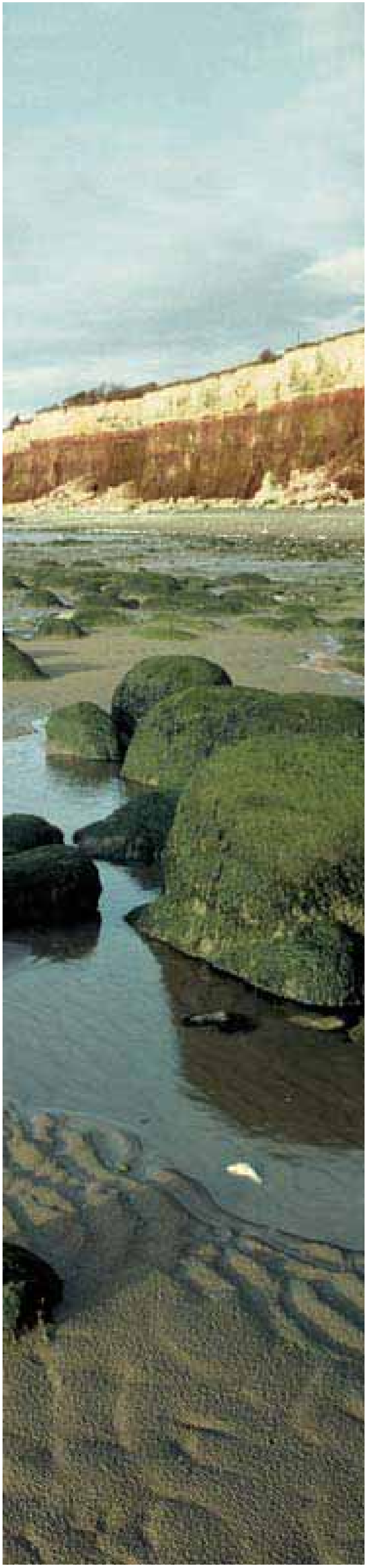
Nature: achieving a balance
By understanding the geological record we can better predict the changing nature of our environment. Understanding the influence of geodiversity on landscapes, soils, habitats and the processes that link them will improve our understanding of ecosystems, help to establish clear and consistent geodiversity indicators to better understand change, and allow us to plan for it.

Acting together
Geodiversity is threatened by development, a lack of consistent planning guidance and policy, and poor land use. Its conservation requires clear and inclusive management set within a framework of integrated planning policies and guidance. Where natural processes are the key to maintaining geodiversity, they must be maintained; where intervention is needed, a process of on-going management must be established.

To achieve these aims, funding for geodiversity on both site and landscape scales needs to be established. We also need to involve a greater range of organisations, groups and individuals in the integrated conservation, management and promotion of geodiversity.

Conclusion
Geodiversity is the link between rock, landscape, soil, biodiversity and the processes that maintain the natural functions of our environment. It provides many of our resources and defines our surrounding environment.

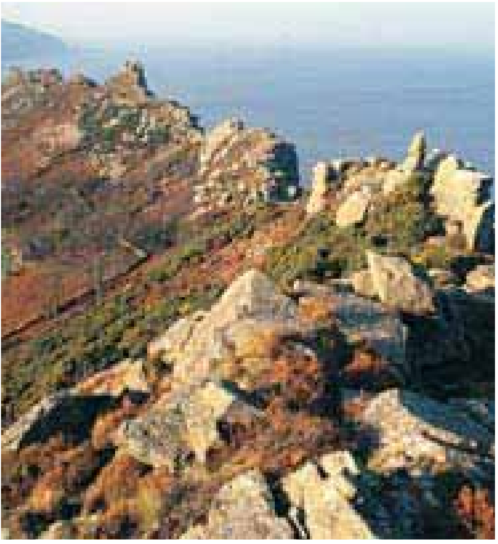
Understanding geodiversity is central to achieving sustainable development in a sustainable environment. This integrated approach is already reflected in the establishment of *Natural England* which brings together English Nature, the Countryside Agency and the Rural Development Service. Establishing an integrated approach for geodiversity, and encouraging our partners to work with us in this way, is a vital objective for *Natural England*.



Red and white chalk cliffs, Hunstanton, Norfolk. Richard Cottle

1 Introduction

England is a country of great contrasts – from the mountains and lakes of Cumbria, to the rugged moors of Devon and Cornwall, and from the rolling chalk downs of Kent, to the peat expanses of the Fens. On the coast the evocative White Cliffs of Dover contrast with major estuaries such as The Wash and the idyllic coves and rocky headlands of Devon and Cornwall.


Peter Wakely/English Nature 17,214

Craggy landscape of the Valley of the Rocks, Exmoor, Devon.

These impressive landscapes shape England's identity. The interactions between geology, geomorphological processes and climate, past and present, influence the character of our landscapes and the nature of our soils. For example, the red rocks and soils of Cheshire, the limestone pavements of the Dales and the expanse of rich black peat in the Fens all influence the distribution and range of their habitats and species. Biodiversity is fundamentally linked to geodiversity, and both have been adapted and changed by man's intervention; from agriculture and forestry to recreation and tourism, and the extraction of fuels, minerals and aggregates.

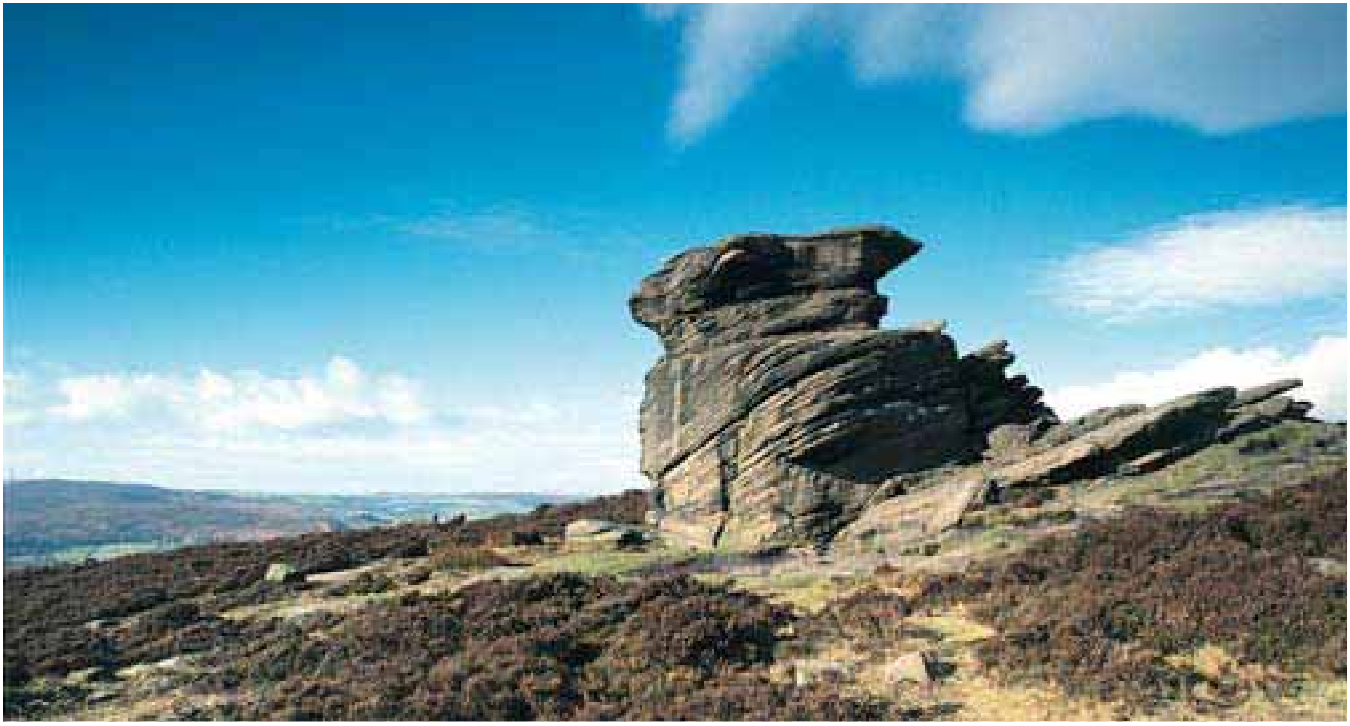
Geodiversity is fundamental to the way our natural environment works and, therefore, to the way we live and work. Geodiversity is also extremely sensitive and vulnerable to damage. Much of geodiversity is a non-renewable resource; for example, landforms and soils once removed cannot be recreated.

What is geodiversity?

Geodiversity is the variety of rocks, fossils, minerals, natural processes, landforms and soils that underlie and determine the character of our landscape and environment. The elements of geodiversity are clearly linked; however, it is important to understand each element separately.

Sweeping beaches on the Isles of Scilly.


Pat Sargeant



Paul Glendell/English Nature 24,060

Geodiversity is an essential element of our stunning scenery on the coast and inland. Gritstone tor, Dark Peak, Derbyshire.

Definitions

Geodiversity
Geodiversity: the natural range (diversity) of geological (rocks, minerals, fossils), geomorphological (landform and processes), and soil features. It includes their assemblages, relationships, properties, interpretations and systems. (Gray 2004)

Biodiversity
Biological diversity – or biodiversity – is the variety of life on Earth and the natural patterns it forms. It is the web of life, and geological diversity – geodiversity – is an essential foundation for this web.

Geology
Geology is the variety of the Earth's rocks, fossils and minerals. Geology is also the study of the Earth's origin, history, structure and composition.

Geomorphological processes
Geomorphological processes are the natural processes of weathering, erosion and sedimentation that maintain our environment.

Landform
Landform is the surface shape of the Earth. Features such as mountains, hills and valleys that are formed by the action of natural processes on the underlying geology are part of landform. Landform is entirely natural.

Landscape
Landscape includes everything, natural and human, that makes an area distinctive: geology, landform, soil, plants, wildlife, and patterns of human land use. It can be viewed in different ways, depending on the different natural and cultural values of the observer.

Soil
Soil is the upper layer of the Earth's crust, composed of mineral particles, organic matter, water, air and organisms, in which soil-forming processes have transformed the parent material (Defra 2004a). Soils link geology with surface habitats, species and land uses.

Mick Murphy/English Nature

Zigzag folds in the rocks at Millook Bay, Cornwall.

Geology

To understand geology it is important to appreciate the vastness of time. The Earth is considered to be about 4,600 million years old and has changed dramatically throughout its history. Continents have come together and moved apart, mountain ranges have been pushed up and worn down, and sea levels have risen and fallen. The climate has constantly changed and life and ecosystems have evolved. Proof of the dynamic nature of the world is all around us. Rocks, fossils and minerals are evidence of past environments, life and the composition of the Earth. Folds and faults show what happens when continents collide and separate: dramatic processes which continue today, causing earthquakes and volcanic eruptions.

Geomorphological processes

Weathering, erosion and deposition by wind, water and ice are the dynamic forces of our environment. They operate over a range of geographical scales from the local to the global and over a range of timescales. Some change is gradual and almost imperceptible, such as the erosion and weathering that forms soils, whilst other changes can be rapid, for example the flooding and erosion which occurs during storms. Soft coastlines erode quickly; rocky coasts form high rugged cliffs. Rivers flow rapidly in upland areas, and they meander slowly across lowland floodplains. Geomorphological processes mould our landscape, influence the distribution of habitats and species and are essential to the way our environment works.

Sand dunes on the North Norfolk coast.

Peter Wakely/English Nature 18,324

Mick Murphy/English Nature

Sea stacks and arches at Land's End, Cornwall.

Landform

Geomorphological processes act continuously to shape the Earth into the landforms of mountains, hills, valleys, floodplains and coastlines we see around us. Landforms can include relict landforms from past environments, such as glacial valleys and moraines, which are now being gradually modified by present-day processes.

Landscape

Landscape encompasses landforms, soils and habitats and the patterns of land use that have been superimposed on them throughout human history. The way people have lived on the land and harnessed its resources can be seen from archaeological remains, changing forestry and agricultural land use, quarries and industry, and settlements, towns and cities. This gives landscape its historical and cultural associations. In recent centuries, technological advances have overcome geological constraints to settlement, and land use now reflects more complex social and economic influences. All these elements combine to create the diverse landscapes of England, providing historians with clues to the past, inspiring artists and contributing to our quality of life.

Soil

The raw materials for mineral soils are derived from weathering of the underlying rock or unconsolidated sediments (peat soils have a different origin, described below). The source rock determines the chemical and physical nature of the soil, which is so important to farmers and gardeners across England. Chalks and limestones lead to an alkaline, usually well-drained soil; sandstones, sands and gravels typically form acidic, well-drained soils; while finely grained rocks such as clays, mudstones and shales often form poorly-drained soil. Local variation may be seen: where sands and gravels are dominantly calcareous then soils will be more alkaline and the calcareous boulder clays that cover much of Eastern England are often moderately well drained.

"Soils are in essence a living organic body that lies between, and demonstrates the integration of, the physical and biological realms of the landscape"

IUCN 2004

Peter Roworth/English Nature

Grey rendzina soil with chalk pebbles, Yorkshire Wolds.

The actions of vegetation and the great mass of soil fauna, influenced by climate and relief, turn this raw material into a variety of soils. For instance, where the growth of vegetation is faster than the decay of organic matter by soil organisms, an organic layer builds up at the surface. This can create thick peat deposits formed from the waterlogged remains of sedges, rushes and sphagnum moss. By contrast, on mountain tops where vegetation growth is impeded by cold climate and substrates poor in nutrients, soils are very shallow and slow to form, and often consist of a very thin organic layer directly overlying weathered rock. Soil organisms continuously recycle organic material, and mix and aerate the soil.

Soils in England are classified into 10 major groups, with about 700 soil types, in about 300 soil associations, reflecting the varied geology of the parent rock. About 40 of these are widespread.

2 England's unique geodiversity

For its size, England is arguably the most geologically diverse country in the world. The Earth is approximately 4,600 million years old. The oldest rocks in Britain, found in Scotland, are 2,800 million years old. In England, the oldest rocks (found in Shropshire, the Malvern Hills and Leicestershire) are about 700 million years old. Since then England has accumulated a sequence of rocks representing every major Period of geological history.

A journey through time

Over the last 550 million years, the land we now call England has journeyed across the globe, experiencing phases of intense mountain building and volcanism and dramatic changes in climate. The rocks that remain provide a series of 'snapshots' of the evolution of life and past extinctions. The examples that follow only scratch the surface of this fascinating, dramatic and ever changing history.

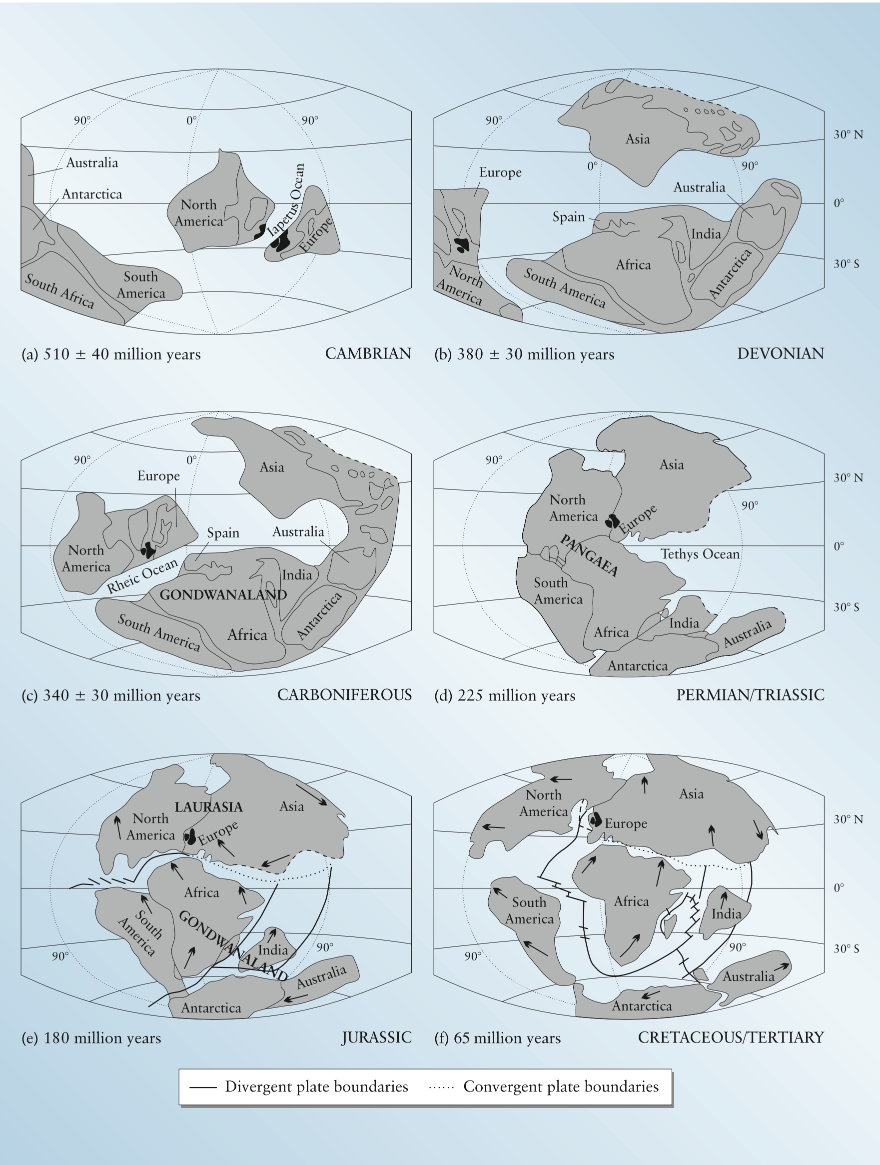
These rocks at Charnwood, Leicestershire, are some of the oldest in England.

Mick Murphy/English Nature

Evolving continents

The continental plate carrying England has slowly drifted over time, driven by a process known as plate tectonics. It has moved from a latitude of 60º–65º south of the Equator (currently the edge of the Antarctic ice cap) across the Equator to the position it now occupies at about 52º in the northern hemisphere. During this time North America has collided with and then drifted away from Europe, ancient oceans have opened and closed, and Africa has driven northwards into Europe.

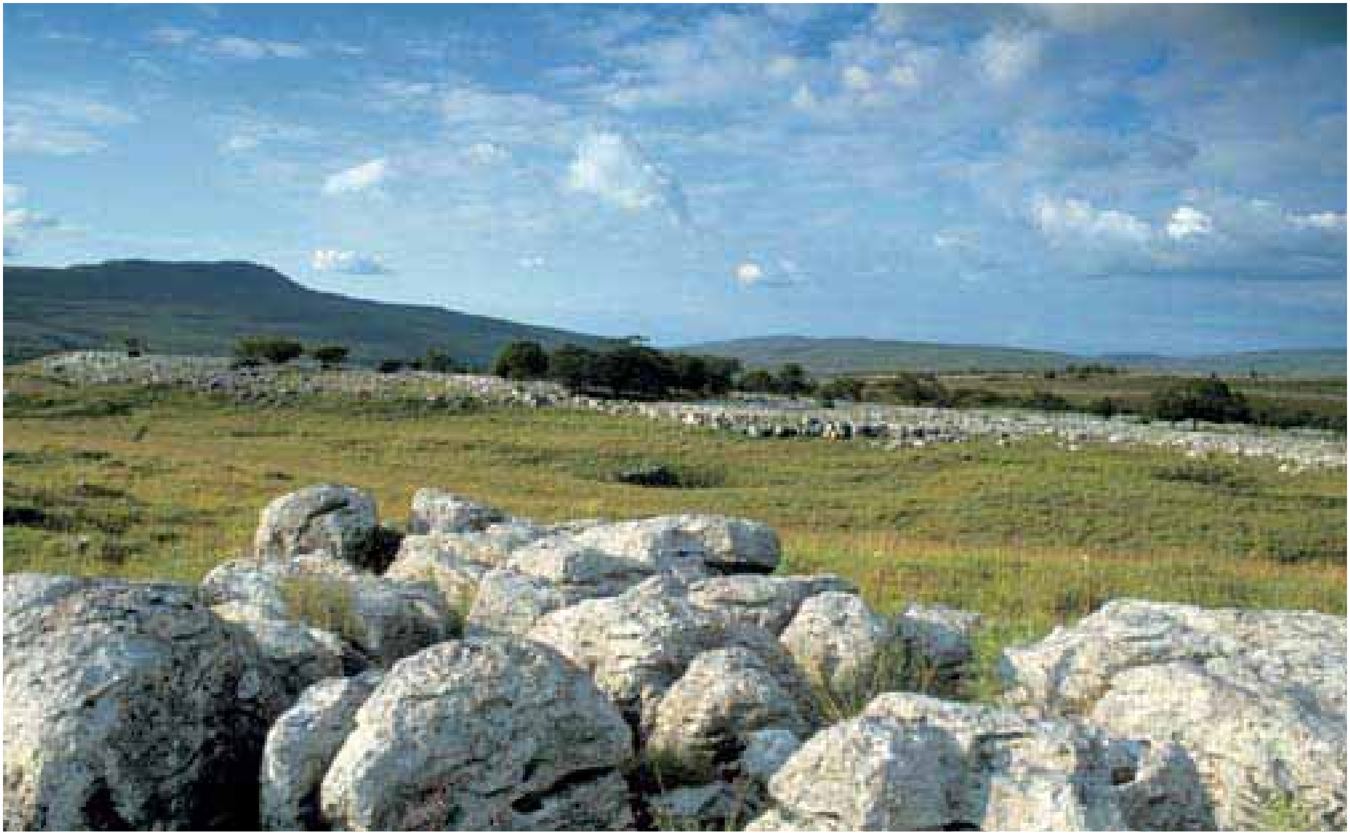
The mountains of the Lake District were pushed up as North America collided with Europe approximately 400 million years ago. The associated volcanic activity left a thickness of six kilometres of lava and ash between Langdale Pikes and Silver Howe. The Dartmoor granite tors, Bodmin Moor and the Isles of Scilly are the remnants of another mountain chain created 290 million years ago, when a vast continent collided with Europe and North America from the south folding and faulting the rocks of the Devon and Cornish coastline.



Continental drift mapping Britain's journey across the Earth (from Ellis and others, 1996)

Granite tors on Bodmin Moor.

Pat Sargeant



Mick Murphy/English Nature

Grey limestones of Ingleborough, Yorkshire.

Changing climate

As England journeyed across the globe it passed through a wide range of climate zones, reflected in the rocks we see around us. The grey limestones of the Mendips, Derbyshire and the Yorkshire Dales accumulated under tropical seas 340 million years ago. The vivid red sandstones of Cheshire were laid down in a hot, arid desert about 250 million years ago. During the last two million years England's climate swung periodically, over tens of thousands of years, from Arctic freeze, under vast ice sheets, at times over a kilometre thick, to tundra and then temperate conditions.

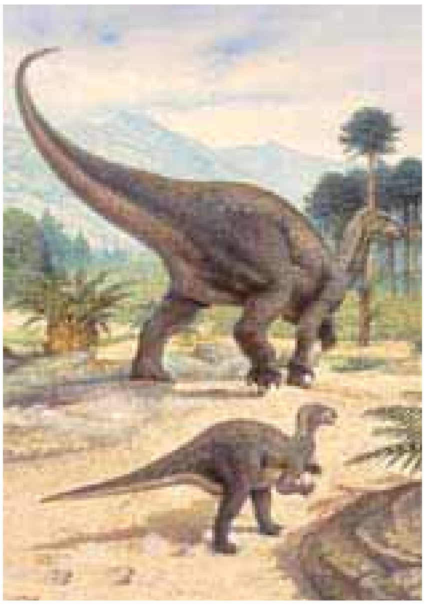
Red desert sandstones, Claverley Road cutting, near Bridgnorth, Shropshire.

Peter Wakely/English Nature 11,448

Graham Worton

Weird and wonderful life on the reefs of the Silurian seabed.

Evolution of life



John Sibbick

Dinosaurs, such as these Iguanodons, left footprints tracking across the landscape of southern England which are today found in the Lower Cretaceous rocks of the Weald and the Isle of Wight.

Life responded to these evolving climates and environments. The evidence for this is preserved in England's particularly rich and diverse fossil record. During this evolution there have been five mass extinctions.

Some of the earliest records of life are found in the Charnwood rocks to the north of Leicester. Here the fossil impressions of soft bodied animals, including jellyfish, have been found in rocks about 600 million years old. The ancient limestones of Wenlock Edge in Shropshire and the Wren's Nest and Castle Hill in Dudley were formed as tropical reefs 425 million years ago. Today the limestones bear witness to the diversity of ancient life with fossil corals and whole reef communities preserved as they originally grew.

Moving forward in time, the soft Jurassic cliffs of Dorset and Yorkshire have eroded to reveal a vast array of Jurassic marine fossils. Best known are the coiled ammonites and the spectacular range of marine reptiles such as *ichthyosaurs*. Recently, a nearly complete dinosaur *Scelidosaurus* was discovered on the coast near Charmouth in Dorset. On the Isle of Wight, the slightly younger Cretaceous rocks are the most prolific source of dinosaur fossils of this age in Europe.

Ammonites on wave cut platform, Monmouth Beach, Devon.

Chris Gibson/English Nature

Over the last two million years, England has seen a great variety of plants and animals. Woolly mammoths, woolly rhinoceroses, elephants and hippopotamuses ranged across the English landscape, stalked by sabre-toothed tigers, hyenas and lions. Early man appears in the English fossil record about 400,000 years ago, at Boxgrove in Sussex, whilst caves in Creswell Crags, in Derbyshire, show evidence of occupation going back 50,000 years.

West Runton Elephant

West Runton, in Norfolk, is famous for the elephant discovered in glacial deposits which are exposed along the coast. The first bones to be unearthed, during a winter storm in December 1990, were the ribs, jaw, backbone and part of a leg. The rest of the skeleton was retrieved in a rescue excavation in 1995.

In life, it probably stood 4 m high and weighed about 10 tons, nearly twice the weight of a modern African elephant. It died aged about forty years old.

Neil Glasser

West Runton cliffs, Norfolk.

Boxgrove Man

Sussex was home to the world famous Boxgrove Man, known from a shin bone and two teeth that were found in a gravel pit just outside Chichester. He was a powerfully built individual, over six feet tall, and is thought be of the species *Homo heidelbergensis*. The river gravels also yielded lots of flint hand axes and numerous mammal bones. This dates them to about 400,000 years ago, making the Boxgrove Man the oldest human so far discovered in Britain.

Alistair Murphy

This fossil elephant, recovered from cliffs at West Runton, tells us about past climates.


Richard Cottle

The Seven Sisters, West Sussex, were formed by dry chalk valleys which have now been eroded by the sea.

Towards a modern landscape

During the last two million years climate change has involved the advance and retreat of thick sheets of ice and glaciers from the mountains of the north and west. These have eroded classic U-shaped valleys into upland areas such as the Lake District and changed drainage patterns in lowland areas. For example, the Thames used to flow through the Vale of St Albans and across East Anglia but was diverted south towards its present course during the Anglian glaciation.

Rock which is eroded, crushed and transported at the base of glaciers forms deposits known as till (boulder clay), which are rich in clay and gravel. Today till covers much of the lowland landscape of northern, midland and eastern England. Locally the meltwater-rivers draining from the glaciers reworked these sediments to form extensive spreads of sand and gravel which are now the largest reserve of aggregates, both on land and offshore.

Although the periods of glaciation were the most dramatic expression of recent climate change, England also had long periods of tundra type climates. These were bleak landscapes of permafrost and polar desert which were subject to powerful physical weathering and repeated freezing and thawing of ice. These forces crumbled and rounded the landscape, for example forming the dry valleys of the chalk downs. With so much water locked up in the ice, sea levels were low, so southern England was connected to northern Europe.

Change goes on

The events of the last glaciation, and the glacial/interglacial transitions, fundamentally changed the landforms of England. Today, geomorphological processes continue, but, alongside this, the activities of humans are much more significant in shaping our landscapes.

Soft till (boulder clay) cliffs of the Norfolk coast.


Keith Duff/English Nature

Peter Wakely/English Nature 21,531

Classic U-shaped glacial valley in the Lake District.

Evidence of the Ice Age in England

Physical evidence

- Glacial erosion in mountainous areas – creating the U-shaped valleys, sharp peaks, ridges and corries reminiscent of the Alps.
- Glacial erosion in lower areas – creating extensive ice-eroded pavements, for example the limestone pavements of the Yorkshire Dales, and striations on rocks which mark the direction of ice flow.
- Landforms created by glacial sediments – moraines marking the edges and snouts of glaciers, eskers marking sub-glacial drainage channels and outwash fans of material released by melting glaciers.
- As glaciers move, the trail of sediments they leave behind can chart their course, particularly where distinctive rocks of limited outcrop are carried across the countryside and left as glacial erratics.
- Changes in drainage – rivers diverted, or dammed by ice to form lakes, and overspill channels from these lakes cutting through the landscape.
- When glaciers melt, land rises as it recovers from being buried under the weight of ice, and the meltwater raises sea levels. Inland, land level rise is shown by river terraces – marking successive river floodplains as the land rises and rivers cut down to new levels. At the coast, raised beaches and wave cut platforms, stranded sea cliffs and caves indicate relative rise of the shore, whilst buried forests and river channels indicate relative sinking.
- Periglacial features – kettle holes, pingos and stone patterns formed by freeze-thaw action and ice heave.

Keith Duff/English Nature

A trail of dark sandstone erratics, carried by ice across the limestone at Norber, Ingleborough.

The fossil record

- Pollen, diatoms and larger plant and animal fossils are particularly well preserved in clays deposited in glacial lakes and in peat soils.
- Trees in particular show marked climatic zonation, so the relative abundance of birch, pine, willow, alder, oak and beech pollen in the fossil record can be used to deduce past temperatures. Overlapping pollen diagrams from across the country have been combined to produce a detailed record of temperature fluctuations.
- Beetles are abundant and sensitive to climate change, and as they are well preserved in the more recent fossil record, provide a good indicator of temperature change.

Dating the evidence

- Each year, the summer thaw carries fine sediment into lakes, to settle out as distinct layers of clay, known as varves. Like the growth rings of trees, these annual layers can be counted back from the present to date deposits up to 10,000 years old.
- Organic material in fossils can also be used for radiocarbon dating, which is reliable as far back as 30,000 years.

Stonehenge – a landscape shaped by prehistoric man.

Keith Duff/English Nature

3 Geodiversity: science and knowledge

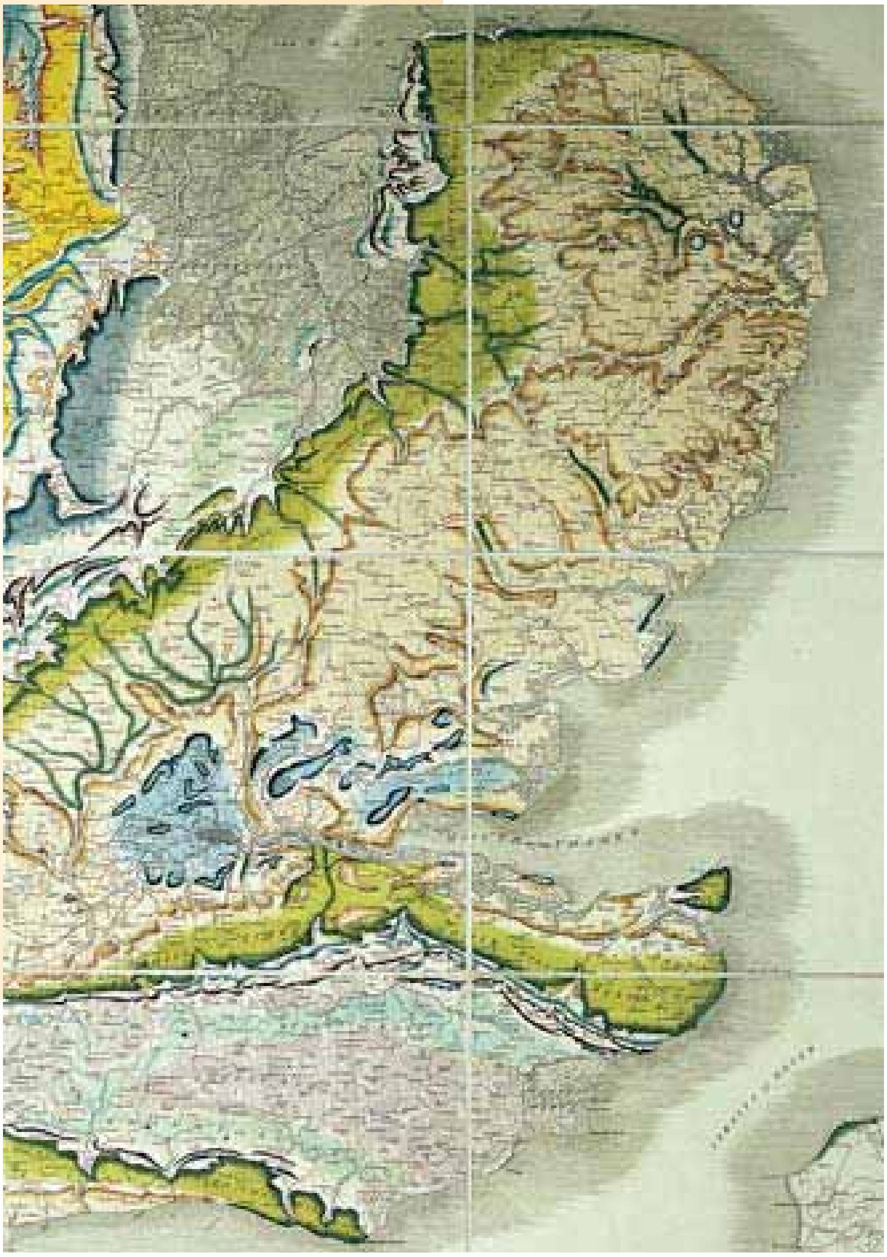
In order to plan effectively for a sustainable future we need to understand our geological past, the natural processes which occur, how they have moulded our environment and the human influences on geodiversity and the landscape.

Britain's geology and geomorphology have global relevance: the abundance and diversity of rocks, fossils and minerals have been central to Britain's pioneering role in the development of the sciences of geology and geomorphology. England has been at the heart of this geological and geomorphological thinking, and continues to drive the modern science forward.

Firsts: concepts and terminology

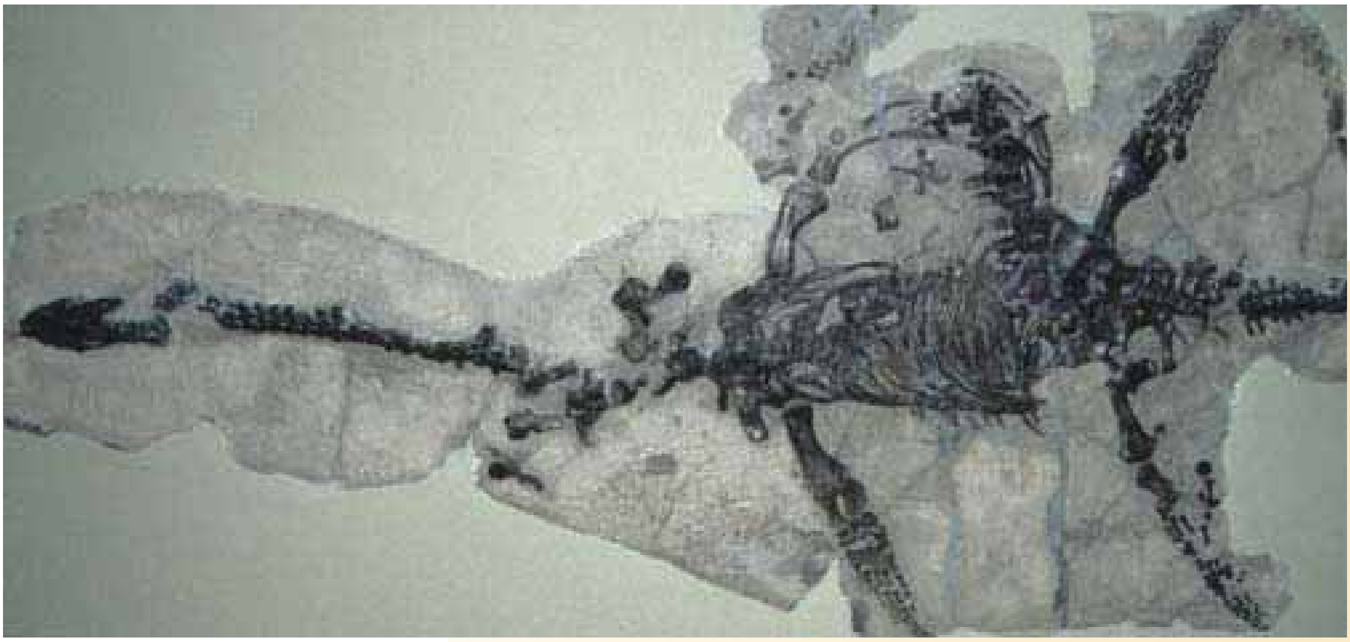
The idea that 'the present is the key to the past' has been central to geology since James Hutton (1795) first realised that the processes we see around us today help us to understand and interpret the geological record. This was the key to realising the immensity of geological time and inspired the thinking of early geologists such as Charles Lyell and natural historians such as Charles Darwin.

William Smith, the 'father of English geology', at the turn of the 18th century observed that certain fossils were often characteristic of particular rocks. This allowed him to compare, or correlate, layers of rock of different ages across England – a principle known as stratigraphy. In 1815, using this principle, he produced the first geological map of England and Wales.



The East and Central portion of William Smith's handpainted 1815 geological map.

Jonathan Larwood/English Nature



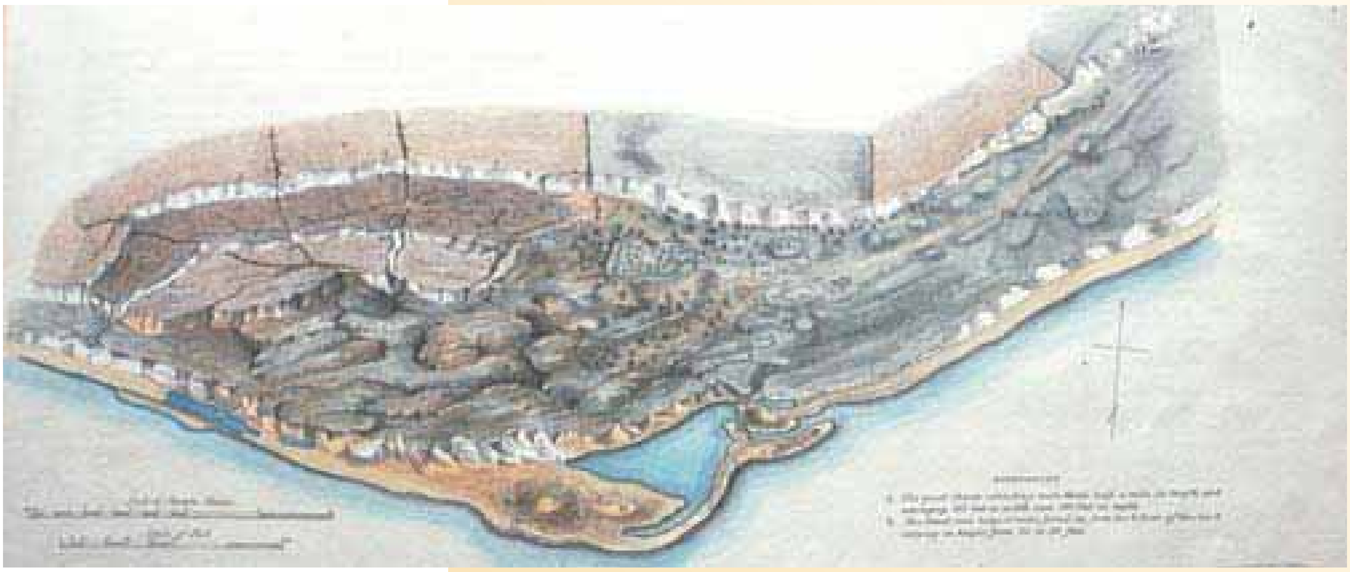
Mary Anning, and one of the *Plesiosaurus* fossils she collected, now in the British Museum of Natural History. Natural History Museum, London

In the 1820s Mary Anning collected and sold Jurassic fossils in Lyme Regis, Dorset. She was only 11 when she found the first recorded marine reptile, *Ichthyosaurus*, eroding out of the rocks. She went on to make more remarkable finds, including the first complete *Plesiosaurus*, in 1823, and the first recorded flying reptile, *Dimorphodon*, in 1828.

In 1822, in West Sussex, Mary Ann Mantell was the first to discover the remains of the large plant-eating dinosaur, *Iguanodon*. This inspired her husband Gideon Mantell to devote his life to the discovery of further fossils, notably *Iguanodon*, and understanding the geology of Sussex. In 1824 Professor William Buckland described a fossil thigh bone from Oxfordshire, naming the animal *Megalosaurus*. In 1841 Dr Richard Owen suggested that *Iguanodon* and *Megalosaurus* should both be called the *Dinosauria* and so was coined, from English fossils, the term dinosaur.

On Christmas Eve 1839 the most dramatic landslide ever to occur in Britain happened on the coastal cliffs at Bindon, near Axmouth in East Devon. William Conybeare was one of the first to examine the landslide. His illustrated account is one of the earliest scientific monographs on the mechanism of a landslip.

Map of the Bindon Landslip by W. Dawson (1840).



Many of the names and terms used today in geological definitions originate in England. The major geological time periods, such as Carboniferous, Eocene, Miocene, Pliocene, Pleistocene and Holocene, were all defined from English geology, but the Devonian has the greatest resonance. It is the period of time between 345 and 395 million years ago, described from rocks of this age in Devon. Similarly, many subdivisions of geological time, Oxfordian, Bathonian, Kimmeridgian, Ludlovian, Wenlockian and Bartonian have their origin firmly in English place names.

Many minerals were also identified for the first time in England. For example wavellite, an aluminium sulphate mineral, was named after its discoverer, Dr William Wavel, an 18th century physician and mineral collector.

These discoveries have helped geologists to understand and predict the location of buried natural resources and made it possible to exploit deposits that were previously unknown or inaccessible. These advances were crucial to the economic, social and cultural development of Britain. For example, coal fuelled the Industrial Revolution, and for centuries Cornwall was the main world producer of tin. In the 20th century, our understanding of on-shore geology enabled the prediction, discovery and exploitation of oil and gas reserves in the North Sea.

Wavellite, a mineral first described from High Down Quarry in Devon.

David Green/University of Manchester

Peter Wakely/English Nature 17,476

Distinguishing natural change from pollution-induced change is essential when planning for the future.

The past is the key to the future

Geological research, using modern-day processes to interpret and understand geological evidence, has built up a picture of past change. This includes gradual natural cycles of change and more rapid changes, often related to extreme events, for example during periods of climate change. The best pointers to the future are the geological changes that occurred in the last two million years and especially in the last 100,000 years.

Human activity, especially the use of fossil fuels, increasing urbanisation and agricultural land-use superimposes additional change on these natural cycles. The combined effects of these activities pose the greatest environmental challenge to modern society. Fossil fuels, mineral resources and fresh water are becoming progressively scarcer. Soils are becoming contaminated and water supplies are becoming polluted. Atmospheric pollution, contributing to global climate change, will bring rising sea levels and changes to weather patterns, including increased storminess and flooding.

Our understanding of the geological past is increasingly being used to predict future change and to assess how the Earth will respond. Importantly, understanding the dynamic past of the Earth allows us to distinguish natural change – over which we have little control – from change caused by human activity, which we may be able to ameliorate. This knowledge is essential to planning for a sustainable environment and in considering how we use the world's resources.

Evidence of changing sea levels

There is plenty of evidence for past sea level change, such as raised beaches, stranded cliffs and sea caves many metres above present sea level. Tree stumps exposed at low spring tides on parts of the coast also show that these areas were once above sea level. By studying these ancient shorelines and other evidence we can chart and analyse past change, and forecast future change, especially in the face of further anticipated sea level rise due to global warming (Humphreys and others 2003).

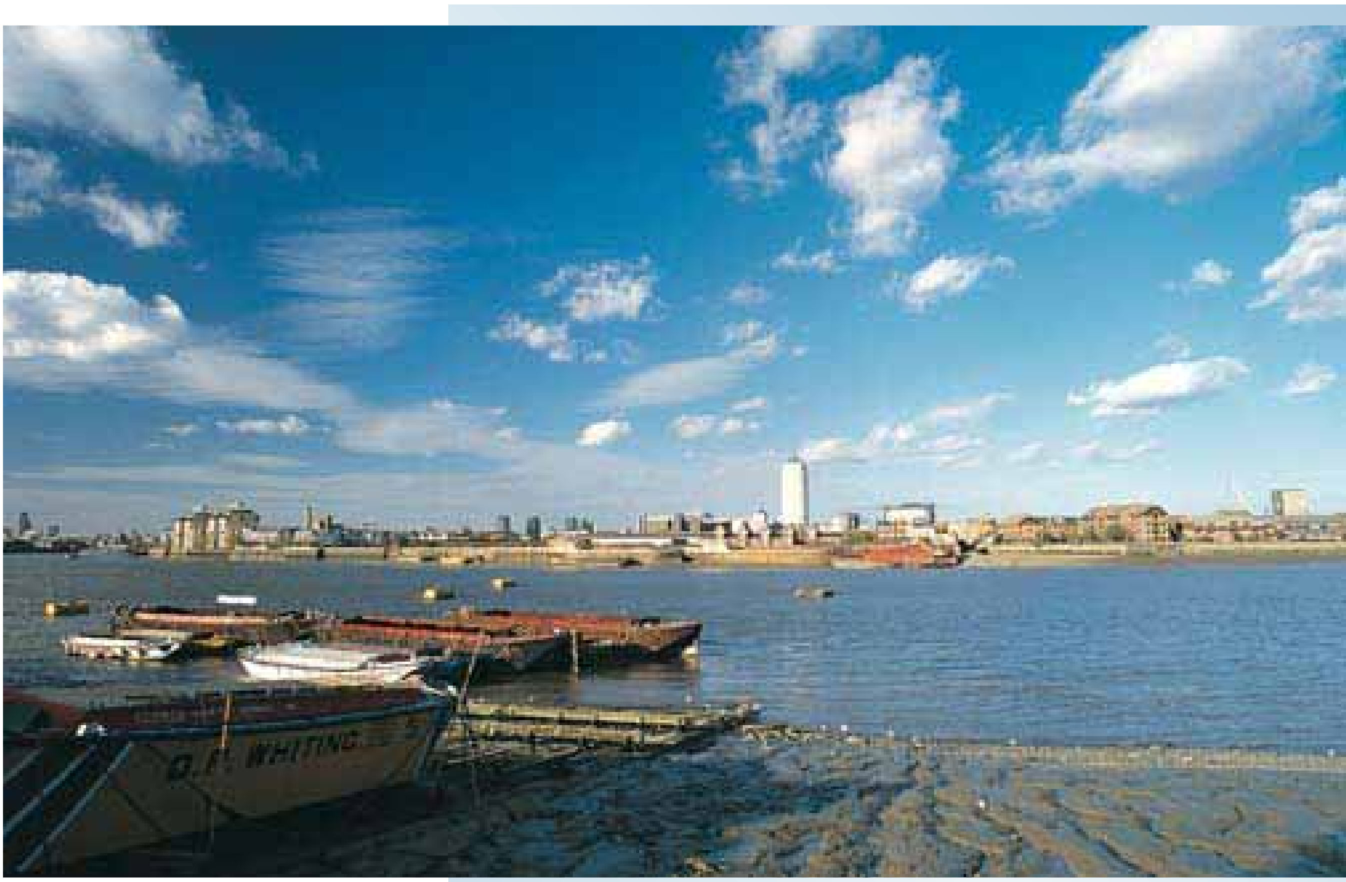
Chris Gibson/English Nature

Successive gravel ridges, now partly cut across by roads and tracks, Dungeness, Kent.

More recently, we have direct historical evidence of change. This includes records of changing sea levels and coastlines, ranging from whole villages lost to the sea to former harbours landlocked by coastal growth. We have records of flood events and changing temperatures, including the Little Ice Age from about 1650 to 1700, the subsequent warming during the Industrial Revolution and recent evidence of global warming.

'*The Frozen Thames*' painted in 1677 during the Little Ice Age by Abraham Hondius. It shows a view over the Thames to the old London Bridge.

British Museum and Heritage Image Partnership

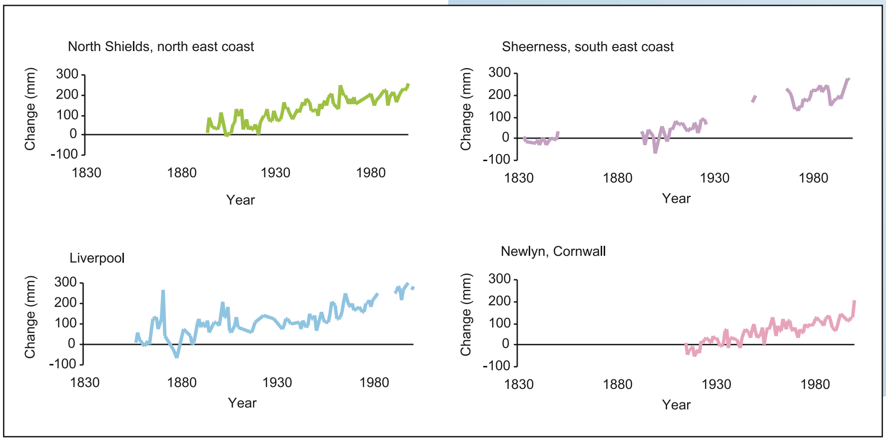

Peter Wakely/English Nature 21,802

Much of London is on low lying land vulnerable to flooding.

Flooding on the River Thames

In 1236 the River Thames was reported as overflowing "and in the great Palace of Westminster men did row with wherries in the midst of the hall" (Stow 1580). Samuel Pepys wrote in his diary on 7 December 1663 "There was last night the greatest tide that was ever was remembered in England to have been in this River, all Whitehall having been drowned."

The last time that central London flooded was in 1928 when 14 people died. In 1953 there was disastrous flooding on the East Coast and the Thames Estuary with a toll of over 300 lives. The frequency of flood events is now increasing, and the Thames barrier has been used 92 times since it became operational in October 1982.



Examples of recorded change in sea level. Permanent Service for Mean Sea Level. (Proudman Oceanographic Laboratory).

4 Geodiversity in a sustainable future

Geodiversity provided the foundation of England's economic wealth, cultural development and heritage through, for example, the exploitation of coal, iron and tin in the Industrial Revolution and of oil in the 20th century. Today geodiversity, whether the raw materials of industrial development, the building materials of towns and cities, agricultural soils or diverse landscapes, is one of England's most valuable natural assets. We must achieve a sustainable economy, however, many of these resources are irreplaceable and achieving true sustainability presents enormous challenges.

Peter Wakely/English Nature 14,047

Ironstone works, Scunthorpe.

The Government's new sustainable development strategy, *Securing the future* (Defra 2005a) commits the UK to sustainable development; "to enable all people throughout the world to satisfy their basic needs and enjoy a better quality of life, without compromising the quality of life of future generations". Sustainable development simultaneously aims for an integration of environmental, economic and social objectives. The Government's strategy has four key priorities:

- sustainable consumption and production;
- climate change and energy;
- protecting natural resources and environmental enhancement; and
- sustainable communities.

Mick Murphy/English Nature

For sustainable development to become a reality, Government, consumers, business and the public must understand the impacts of their actions. Geodiversity sets the scene for sustainable development in all four key areas.

Geodiversity: setting the scene for sustainable development

Geodiversity makes an important contribution to delivering sustainable development through:

Sustainable production and consumption

Geodiversity underpins our economy through the production and management of essential materials. Knowledge of geology is vital to the continued exploitation of resources, to major engineering projects and development, and to finding alternatives to non-renewable resources. Our varied landscapes are increasingly contributing to our economy through tourism.

Climate change and energy

Understanding climate change in the geological past, and the mechanisms that drive it, will be crucial in developing strategies that mitigate global climate change and address its impacts. Geodiversity has a fundamental role in energy production, both through fossil fuels and in new renewable energy technologies.

Natural resource protection and environmental enhancement

Geology, landform, landscape and soils are natural resources in need of protection. They provide essential environmental benefits and are crucial to the delivery of sustainable environmental enhancement.

Sustainable communities

Landscape, whether rural or urban, provides communities with a ‘sense of place’ and provides people with artistic and spiritual inspiration. Geodiversity provides varied and inspiring backdrops for those participating in healthy outdoor activity, while geology is an excellent subject for enthusing children and for life-long learning.

Rocks at Porthleven, Cornwall.

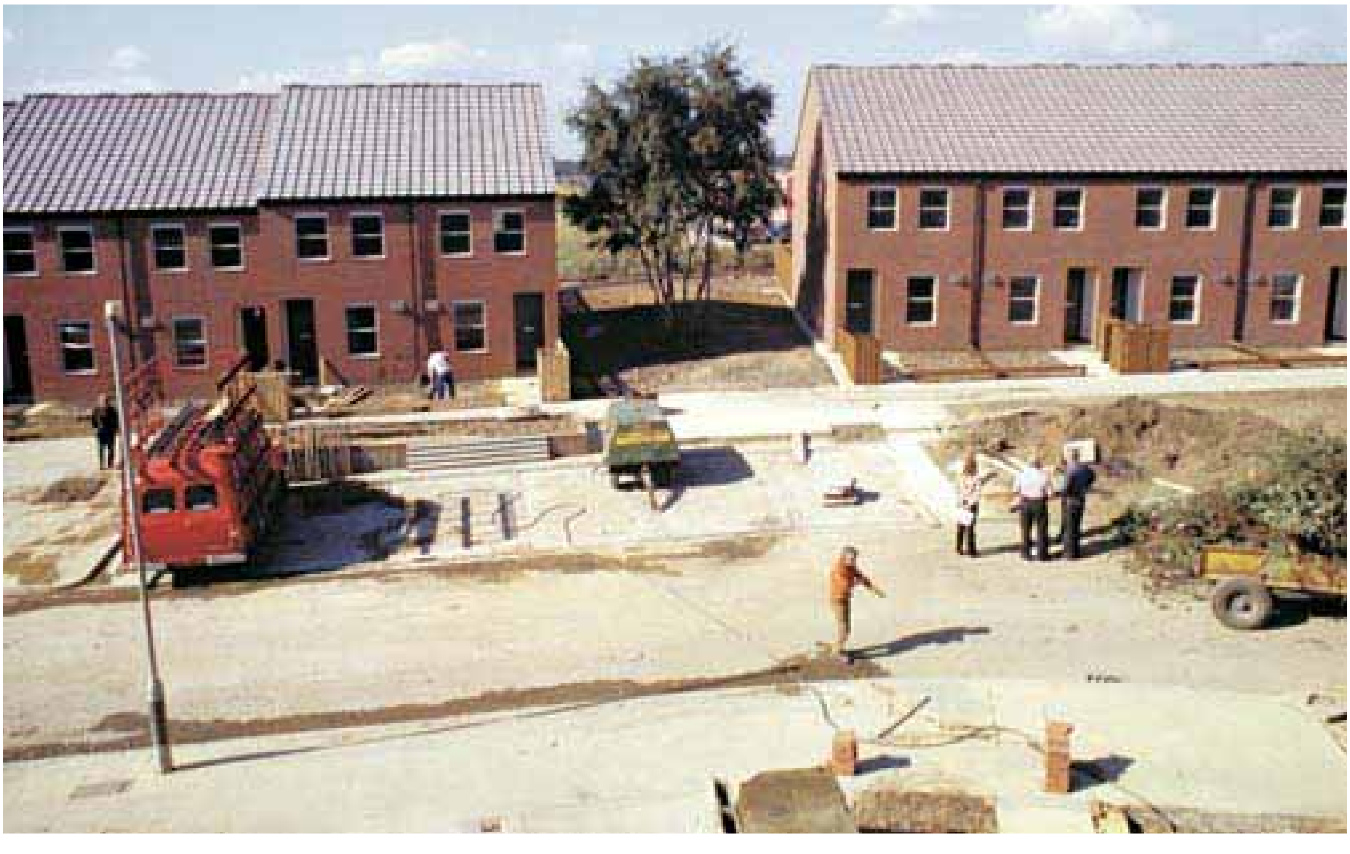
4.1 Sustainable consumption and production

Geodiversity – underpinning our economy

In the modern world many of our most basic commodities are already highly modified before purchase, so that most people are unaware of our fundamental dependence on geological materials and processes. Fossil fuels, building materials and precious metals are the foundation of the global economy. Oil is the raw material for a diverse range of plastics. Building stones and aggregates are essential for modern development. Metals are used to create essential structural supports for buildings and the major components of vehicles. They are also an essential part of many other commodities and products, from light bulbs and computers, to electrical and telecommunication wiring. We refine and use a wide variety of other geological products, including china clay, fullers' earth, high grade sands and clays.

Soil and other superficial deposits sustain rural and industrial economies. Their diversity and location determine their use and value. Their mineral content, pH, structure and porosity determine the agricultural crops and timber grown on them. Their composition and physical structure dictate their value as the foundation for built development and infrastructure. These different uses are not always mutually compatible and can have adverse effects on soil functions such as mitigating or emphasising climate change, flood control and aquifer recharge.

A new house requires some 50 tonnes of aggregates.



English Nature

Tourism and the natural economy

Landscape and scenery play an increasing role in tourism because of their aesthetic appeal and the opportunities they offer for recreation. Rural tourism supports around 380,000 jobs and 25,000 small and micro-businesses in rural England (representing nine per cent of jobs, compared to only six per cent in agriculture) and contributes around £31.8 billion annually to the rural economy (Defra 2004b). Tourism can bring jobs and wealth to rural areas, particularly areas such as National Parks, Areas of Outstanding Natural Beauty (AONBs) and Heritage Coasts. Overseas visitors are attracted by England's varied landscapes as well as our history and culture.

Many protected landscapes, such as the Lake District, the Peak District and much of the coast, that are valued for tourism have spectacular and fascinating geology. These are increasingly the focus for 'geotourism,' which draws on public enthusiasm for rocks and fossils, especially dinosaurs, to attract visitors and encourage them to experience, understand and appreciate geology and fossils. The recent establishment as European Geoparks of the North Pennines AONB, and the Abberley and Malvern Hills recognises both their geological value and the contribution this makes to sustainable economic development through geotourism.

Guided walk on the Crickley Hill 'rural geology and landscape trail'.

Gloucestershire Geoconservation Trust

The consequences of unsustainable use

The accelerating pace of development places increasing pressures on geodiversity. Mismanagement and lack of understanding of our diverse natural resources has both economic and social consequences. For instance, inappropriate management of soils not only reduces their agricultural capacity but also leads to wider impacts, such as water pollution from silt and nutrients. These problems can be expensive to address involving, for example, remediation costs for eroded and contaminated land, dredging to maintain silted navigation and drainage channels, and the costs of restoring eutrophic and silted freshwater habitats.

Secondary impacts of housing and infrastructure

Social and economic pressures generate increasing demands for new housing, industry and transport, particularly in the south east of England. This requires building material and aggregates.

Peter Wakely/English Nature 10,593

Gravel extraction near Morden Bog, Dorset.

Aggregates have low value compared to transport costs and are therefore generally extracted in areas close to the required development, particularly on the urban fringe of major settlements. Quarrying and associated infrastructure, including transport links, can have a direct impact on the quality of landscape. Also, many designated landscapes are in upland areas which are often a major source of non-renewable aggregate and building materials. However, in the south east in particular, the usual sources of aggregates, for example river terraces and valley floors, have largely been exhausted, built over, or are subject to environmental constraints. This means aggregates will have to be brought in from other areas, which may include offshore dredgings.

Mineral extraction for aggregates.

Peter Wakely/English Nature 19,345

Building materials, whether mined or quarried, have to be processed and transported to site. These processes demand energy. The use of locally sourced building materials, or locally recycled material, such as road scalpings, reduces transportation costs and support rural employment and skills. Recycling also has a net benefit on the landscape. Better building design can increase energy efficiency by improving solar gain and thermal capacity, natural lighting, and insulation (Architype Ltd 2004).

Geological and geomorphological processes created England's mineral deposits, shaped the landscapes, and created the soils. These operate over very long timescales, and cannot be re-created within a human timeframe. Minerals, once extracted, fossil fuels, once used, and soils, once eroded, cannot be renewed. We need a major shift to deliver new products and services with lower environmental impacts across their lifecycle, and new business models which meet this challenge whilst boosting competitiveness. Increasing emphasis will be placed on resource efficiency including reuse and recycling and seeking alternative materials.

Reduce, reuse and recycle

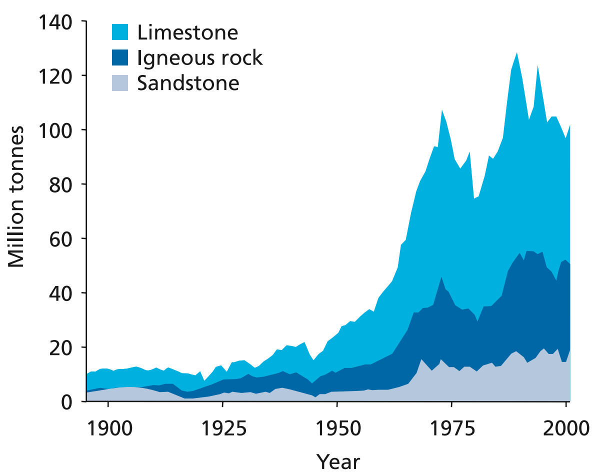
Demand for aggregates, which peaked at some 300 million tonnes a year in 1989, has now settled at around 210 million tonnes, but is expected to increase by about five per cent by 2011. The Government has set targets for increasing the use of recycled and alternative sources of aggregate to 60 million tonnes per annum by 2011. This switch will be promoted through:

- the Aggregates Levy that makes recycled aggregate relatively cheaper;
- Government procurement policies that encourage the use of recycled material;
- landfill tax to encourage recycling of demolition waste, and other waste material, in order to replace primary aggregates; and
- increasing confidence in the utility and quality of recycled materials, as they become more widely available and used within relevant industries.

The industry is committed to minimising the use of primary aggregates and is investing heavily in facilities to maximise the proportion of recycled and secondary aggregates. Recycling is also relevant to a range of other geological resources such as metals and glass both in terms of processing waste and re-using material that has been used and scrapped. Secondary uses are also being found for materials previously regarded as waste. For example, waste from china clay and slate quarries can be used for aggregates and ash from power stations can be used to make breeze blocks.

Aggregate production has increased to meet the demand for housing and infrastructure.
(Hillier and others 2003)

Production of aggregate in the UK, 1895 to 2001



Source: British Geological Survey, 2003

4.2 Climate change and energy

Geological processes, climate and energy are closely linked. Climate, ocean currents and regional and global weather patterns are determined by the distribution of continents and oceans which, in turn, are shaped by geological processes such as mountain building and tectonic movement. The planet has been through many natural climatic cycles. Some have been slow, lasting tens of millions of years, whilst others were more rapid.

England's glacial history

Studies of England's geology have played a crucial role in unravelling the events of the last glaciation. They show that the Ice Ages consisted of a series of glacial and interglacial periods of varying lengths. During the cold glacial periods, ice accumulated and glaciers advanced. During warmer interglacial periods, the glaciers melted and plants and animals re-colonised. England, being on the fringe of the ice fields, preserves crucial evidence of this advancing and retreating ice (see Section 2).

We know this by studying both the physical landforms created by glacial processes and the fossils preserved in periglacial and interglacial sediments. The evidence can be dated very precisely to establish a chronology for these events. Careful studies, to interpret and collate this evidence, have unravelled the history of the last Ice Age in England.

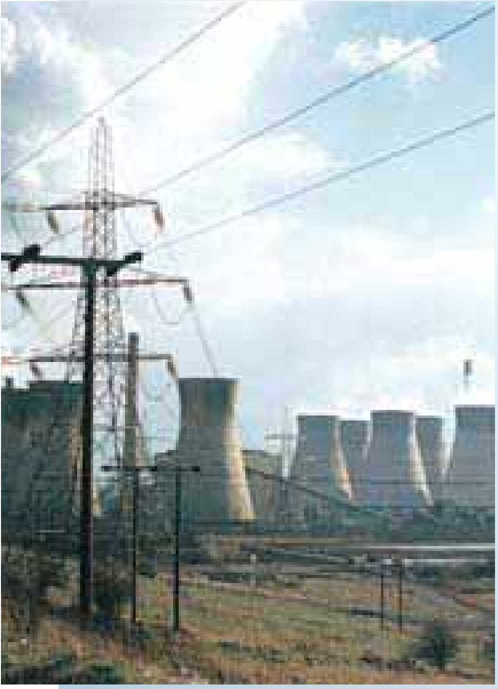
Skeleton of a woolly rhino, an animal typically associated with a tundra-like environment. The skeleton is dated at approximately 40,000 years old and was recently discovered in a sand and gravel pit in Staffordshire.

G. Coates, Field Archaeology Unit, Birmingham University

Predicting future changes

Geological evidence from England has given us great insight into the processes that operate during climate change and how these influence the environment and landscape, including their effects on plants, wildlife and their ecosystems. Understanding past natural climate change and its causes and effects has been aided by complementary studies across the world. For instance, air bubbles trapped in the Antarctic ice sheets have enabled us to trace historical changes in oxygen isotopes and levels of carbon dioxide back 500,000 years. Similar data from ocean floor sediments provides information that can be traced even further back in time.

Human activities, especially the way we use energy, now superimpose further changes in climate on these natural cycles. Energy demands underpin most aspects of our economy and day-to-day lives. However, the use of fossil fuels, which provide most of our energy, releases gases such as carbon dioxide into the atmosphere. These gases form a insulating layer in the upper atmosphere, limiting the escape of heat from the surface of the Earth, creating a greenhouse effect. Population growth and changes in lifestyle have increased the demand for energy, so that greenhouse gas emissions are accelerating and rapidly modifying natural systems to cause global climate change.



Derek Ratcliffe/English Nature 215

The energy industry still relies on finite, diminishing sources of fossil fuel such as coal, oil and gas.

Energy and climate change

The UK currently releases about three per cent of global greenhouse gas emissions, despite having only one per cent of the world's population. In 2003, about 75 per cent of UK electricity was generated from fossil fuels, just over 22 per cent from nuclear sources, and less than 3 per cent from renewable sources. Hence fossil fuels make the largest contribution to greenhouse gas emissions, generating over a third (54 million tonnes) of the carbon dioxide emitted in the UK (see: www.dti.gov.uk/renewables/renew_1.1.htm [Accessed 5 May 2005]).

The Government has signed the Kyoto Protocol, which commits the UK to reducing greenhouse gas emissions by 12.5 per cent on 1990 levels, by 2012. The Government's Climate Change Programme set out its proposals for meeting these targets, and seeks to reduce carbon dioxide emissions further, to 20 per cent below 1990 levels by 2010.

- In the Energy White Paper *Our energy future – creating a low carbon economy* (DTI 2003) the Government pledged to cut current carbon dioxide emissions in the UK by 60 per cent by 2050.

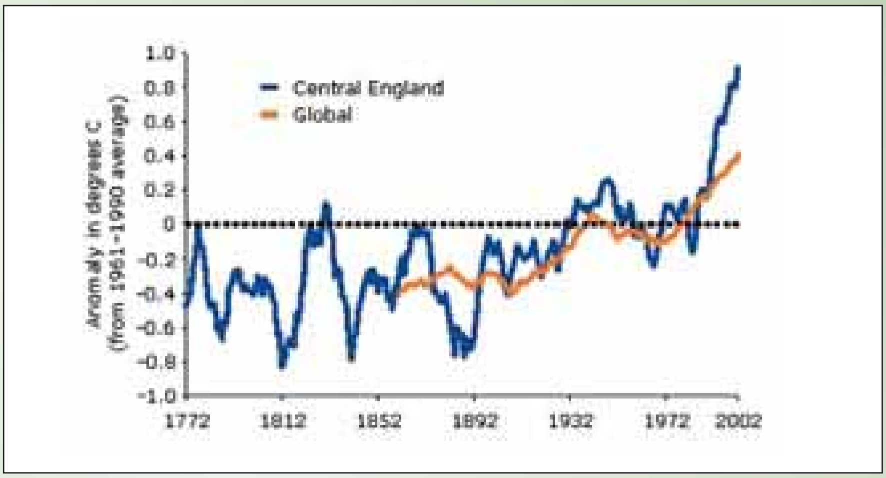
- The Government has set a target for generating 10 per cent of UK electricity from renewable sources by 2010, with an aspiration to double this by 2020.

There is now scientific consensus that global climate change is real and that it poses a major threat to the world we live in. Evidence suggests that sea levels will rise, average temperatures will increase and weather patterns will change. The impacts are already obvious; for example, polar ice sheets and glaciers are retreating, and extreme weather (floods, droughts and storms) is becoming more frequent. There is a significant time lag between the emission of greenhouse gases and the subsequent effects on climate. Even if emissions were drastically reduced now, significant effects are inevitable. Surface temperatures will continue to rise for several decades and sea levels will rise for several centuries.

Global climate change

Changes already observed (Hulme and others 2002) include:

- A rise in the average global surface temperature by more than 0.6 ºC since the beginning of the 20th century, with 0.4 ºC occurring since the 1970s.
- The 1990s noted as the warmest decade in central England since records began in the 1660s.
- Winters across the UK have been getting wetter, with a large proportion of the precipitation falling on heavy rainfall days.
- There has been an increase in annually-averaged sea surface temperature of about 0.6 ºC over the last 70 to 100 years, with a substantial increase over the last 20 years.
- Rises in mean sea level have increased, since 1850, ranging from 0.6 mm per year at Aberdeen to 2.0 mm per year at Sheerness, equating to a sea level rise of about 1.0 mm per year.



Rise in average global temperature 1772–2002. (From www.sustainable-development.gov.uk)

Predicted future change

The UK Climate Impacts Programme has modelled four scenarios for climate change based on different global greenhouse gas emission scenarios. Under these scenarios:

- UK climate will become warmer – the annual average temperature may rise by between 1.5 ºC and 3.5 ºC by the 2080s.
- High summer temperatures will become more frequent and very cold winters will become increasingly rare.
- Summer precipitation may decrease by as much as 50 per cent, and winter precipitation increase by up to 30 per cent, by the 2080s.
- Relative sea level rise will continue to increase around most of the UK shoreline. By the 2080s the sea level may be between 26 cm and 86 cm above the current land level in south east England.
- The strength of the Gulf Stream, that warms the seas around England, may decline by as much as 25 per cent by 2100. (This is unlikely to result in cooling of the climate, due to a predicted steady increase in air temperature from other effects).
- There may be an increase in the risk of winter floods and summer droughts in some eastern locations by as much as 90 per cent in any one year by the 2080s.
- Sea surface temperatures may rise by between 2 ºC and 4 ºC in our shallowest seas by the 2080s.

Dealing with the impacts

Geological evidence of how the planet has responded to past climate change will be crucial to predicting how it will respond to present and accelerating global climate change. It will inform future strategies for mitigating these changes and adapting to unmitigated effects.

The processes which constantly shape landforms and landscapes will change as weather patterns are modified and as sea level rises. This is likely to have significant impacts on river catchments and coastal processes with anticipated increases in future flooding. Management of the coast and river catchments will need to be adapted to respond to and accommodate dynamic change, rather than attempting to overcome it. New strategies for coastal defence need to include managed realignment or reductions in seawall maintenance standards. This should maintain natural coastal processes for the longer term, but may change the nature of important freshwater habitats on the coastal floodplain. This could be balanced by re-creation of wetlands on river floodplains to accommodate river catchment changes and restore past losses.

Spurn Head – some sea defences will no longer be sustainable.

Paul Glendell/English Nature 25,936

Paul Glendell/English Nature 25,060

Upton upon Severn, Worcestershire (2000) – climate change will increase flood risk along river corridors.

Climate change and future flooding

Under all climate change scenarios, the incidence of flooding in England will rise. Rising sea levels could increase the frequency of coastal flooding by 4–10 times and higher levels of precipitation will cause increased flooding along rivers, estuaries and in urban areas.

The Government report *Future Flooding* (Foresight 2004), has drawn on the best available scientific evidence to assess future flood risks. This information informs long-term policy for flood and coastal defence in the UK between 2030 and 2100. This shows the risk of flooding and coastal erosion, under all four scenarios considered, increasing greatly over the next 30 to 100 years, particularly along major estuaries and around the south east coast.

- The number of people at high risk from river and coastal flooding could increase from 1.6 million today, to between 2.3 million and 3.6 million by the 2080s.
- Urban flooding, caused by heavy rainfall overwhelming drains, affects approximately 200,000 people today but this could increase to between 700,000 and 900,000 by the 2080s.

Successful management of climate change will significantly reduce the challenges we face in the longer term, but cannot alleviate all the risks. The most effective and sustainable approach requires a range of actions designed to improve catchment-wide storage of water, limit development in vulnerable areas and realign coastal defences.

Breaching the sea wall at Tollesbury, Essex.

Peter Wakely/English Nature 19,088

Simon Melville/English Nature

The beech woodlands of southern and eastern England could be casualties of climate change due to summer droughts.

Changing climate patterns may affect landscapes, particularly through changes in the viability of current agricultural crops and changes in the distribution of species and habitats. Evidence from the past emphasises the importance of connectivity within the landscape to allow the dispersal and survival of species as the climate changes. Ecologists, planners and landscape practitioners have started to respond to this in various wide-scale conservation and management initiatives. These draw on Joint Character Areas and Landscape Character Assessments to inform the management decisions made for future landscapes. Socio-economic and environmental drivers for change will need to be taken into account. Geological evidence and the interpretation of climate change implications will need to inform conservation objectives, the review of Biodiversity Action Plans, Government Public Service Agreement targets and nature conservation monitoring strategies.

Climate change will modify key soil processes and functions. Raised summer temperatures and drought can ‘burn’ organic material out of thin soils, with adverse effects on soil structure, water regimes and plant growth. The increased intensity, duration and volume of winter rainfall will increase soil erosion rates, especially where soils are already compacted or damaged. These changes will reduce the agricultural capacity of soils and limit other soil functions, including its buffering role as a sink for carbon dioxide and aerial pollution. Defra has commissioned the National Soil Resources Institute to undertake a study of the impacts of climate change on soil and its functions in England and Wales. This study will look beyond agricultural soils to the vulnerability of non-agricultural soils, including urban soils.

In all aspects of future planning, understanding past and present geological processes will be crucial in the development of adaptive land management policies and strategies to address the impacts of climate change. We need to plan for the future, whilst bearing in mind that many of the impacts are inter-related, difficult to forecast and could be more severe than current predictions indicate.

4.3 Natural resources and environmental enhancement

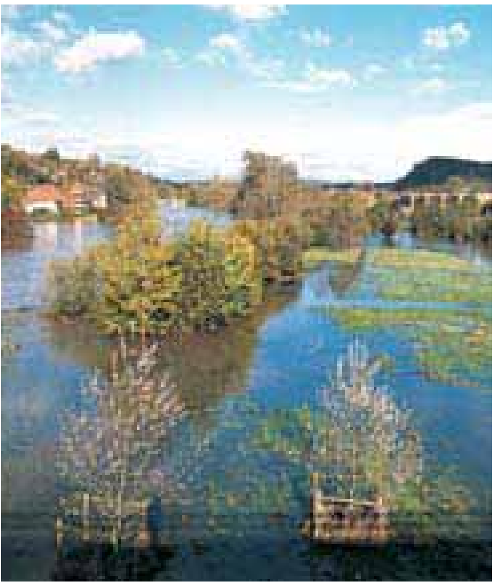
Geology, landform, landscape and soils have a value in their own right and are vital natural assets that need to be protected and conserved. They support wildlife habitats and provide a range of environmental benefits, such as buffering pollution.

Maintaining environmental benefits from geodiversity

Geodiversity is integral to naturally functioning ecosystems, which provide many environmental benefits essential to our continued wellbeing. Dynamic systems evolve naturally and their resilience depends on being able to adapt fast enough to keep pace with change. However, the rate of change in the environment has accelerated as human activity places increasing stress on natural systems. Where these become excessive, natural processes can fail and this often happens very suddenly once a critical threshold is exceeded. The resultant social, economic and environmental problems can be difficult and expensive to address. For example, engineered sea defences that protect economically important assets can starve adjacent areas of sediment and cause increased rates of erosion further along the coast. We must protect England's natural resources by working within their environmental limits.

Working with natural processes, rather than against them, is more successful and cost effective than attempting to halt them and then incurring costs and problems later on. Overstrand, Norfolk.

Keith Duff/English Nature


Paul Glendell/English Nature 25,247

Natural flood plains protect built development.

Managing water

Rocks and soils, relief and vegetation regulate the speed, volume and pathways of water flow in catchments, to attenuate rainfall and limit flooding. They soak up water to recharge the aquifers which supply essential base flow to rivers and lakes, and from which we draw our drinking water. Effective storage reduces the rate of runoff into water courses, while natural channels, which have not been artificially straightened, slow down the flow of flood waters, reducing the height and duration of flood peaks. Where poor land management reduces infiltration, or inappropriate drainage and channel modifications speed up the conveyance of water through the catchment, flood water peaks are increased (English Nature and others 2003). Naturally functioning flood plains store flood water and help to protect valuable urban, residential and industrial assets from flooding. Their wetlands trap sediment and their soils act as natural water filters, improving nutrient recharge in the flood plain and reducing sediment and nutrient loss to rivers.

These issues will be considered by the Environment Agency in the preparation of Catchment Flood Management Plans. They will assess the sensitivity of catchments to flood risk, taking into account land use, development and climate change, to determine options for flood risk management. Options that change land use in flood plains to allow more frequent flooding, or reduced standards of drainage, could potentially provide a range of public and private benefits including flood defence for urban areas, biodiversity enhancement, improved water quality, groundwater recharge and new business opportunities linked to wetland crops or sustainable outdoor leisure and tourism.

Sewage waste being spread on agricultural land.


Paul Glendell/English Nature 22,610

Absorbing pollution

Soils absorb sulphur dioxide deposition from the air to varying degrees, according to their mineral content and acidity. Their biological components have a vital, but poorly understood, role in maintaining soil structure and productivity of our crops. They regulate environmental processes such as decomposition, and nutrient and carbon cycling. They also act as water filters and purifiers. Furthermore, they absorb, degrade and neutralise both bacteria that are harmful to human health and a wide range of industrial, domestic and agricultural pollutants.

Peter Wakely/English Nature 8,830

Peat harvesting removes peat, but also causes further degradation due to drainage and drying out of the peat and reduces peatland capacity for carbon storage.

However, limits to the ability and capacity of soils to degrade these materials have raised concerns about the accumulation of contaminants, such as heavy metals, and the potential risks to public, animal and plant health from spreading organic wastes on farmland. The role of soil in processing waste is likely to increase due to the Government's *Waste Strategy* and the *Landfill Directive*, both of which set targets for reducing biodegradable municipal waste going into landfill. The increased volume of biodegradable material spread on soils could potentially lead to higher levels of nutrient inputs and raise levels of nitrates and phosphates in groundwater and surface waters. Waste Management Licensing will be increasingly important in protecting the environment and human health, and new arrangements have been put in place to ensure that land spreading proposals have ecological or agricultural benefit.

Buffering climate change

Intact peatlands act as major sinks for carbon, storing 25 per cent of the soil carbon reservoir in only three per cent of England's area (Maltby & Proctor 1996). Many peatlands have been damaged by the combined effects of air pollution, sheep grazing pressure, uncontrolled fires, climatic change, trampling and natural erosion and weathering. Such degradation can cause oxidation of the peat, releasing carbon dioxide and reducing the carbon storage capacity of peatlands. Restoration may cause a short-term increase in carbon release, but should be balanced by long-term protection of the areas against further erosion. More needs to be known about the role of organic carbon in soil as a source and sink of carbon dioxide and the implications of this role in the context of climate change (ADAS 2003).

Pat Sargeant

Cornish path-moss is found at only two sites in the world, both on copper-rich mine waste in east Cornwall.

Supporting habitats and species

The intricate interactions between geology, natural processes, landform, landscape, soils and climate are fundamental to the distribution of habitats and species.

Geodiversity, including its influence on climate and terrain, is the major influence on the location and pattern of habitat at a range of scales, including the landscape scale. There is a clear relationship between geology, surface landforms, soils and the original natural distribution of woodlands, heathlands and grasslands across England (Hopkins 2003). Within these broad landscape and habitat types there are subtle variations in response to changes in altitude, slope and aspect, soil nutrient content, water chemistry and hydrology. This natural variability in biodiversity is a reflection of England's geological diversity.

Cornish path-moss.

Pat Sargeant

Some plants, mosses, liverworts and lichens have very exacting requirements and are entirely dependent upon specific geological or topographical conditions, soils and drainage. For example, 'copper mosses' tolerate heavy metals and metal sulphides and grow on thin mineral soils or directly on rock – *Grimmia atrata* grows on acidic heavy metal bearing rocks and Cornish path-moss is a specialist of copper-rich mine spoil. The Teesdale sandwort lives solely on restricted outcrops of the Sugar Limestone in Teesdale and alpine penny-cress and forked spleenwort live on metalliferous and fluorspar outcrops of the Carboniferous Limestone of the Pennines.

Changing land use, land management systems and the introduction of new species, has been superimposed on this geological backdrop. Many habitats have been lost and fragmented, so that the original patterns are no longer obvious in the landscape today. Geology, topography, soils and climate, however, remain important factors in habitat management, restoration and re-creation and the maintenance of functioning ecosystems.

Peter Wakely/English Nature 22,906

The pasqueflower found in the limestone grassland at Barnack Hills and Holes NNR owes its survival to exploitation of geological resources.

Limestone dales and chalk grasslands

Calcareous grasslands have a rich flora and fauna, including many nationally rare and scarce species, such as dark red helleborine, lady's slipper orchid, pasqueflower, and the Duke of Burgundy butterfly.

Many specialised species depend directly on the calcium in limestone or chalk. For example it is needed by snails to build their shells, such as the rare British whorl snail which is restricted to the short dry calcareous maritime grasslands of the south coast of England.

But geology also has more subtle influences, for instance on soil moisture and the physical structure of habitat. Relatively slow-draining, soft chalk has a different flora from that of hard, rapidly-draining limestone pavements.

Outside the downs and dales, many important limestone grasslands are found on the remains of limestone or lime quarries, because these have been difficult to improve for agricultural use. For example, Barnack Hills and Holes National Nature Reserve, renowned for its pasqueflowers, contains the remains of medieval quarries, which were the source of stone for Peterborough Cathedral.

Plants growing in the grikes on limestone pavement are protected from wind erosion and grazing.

Peter Wakely/English Nature 19,706A

Paul Glendell/English Nature 22,751

Heather picking out remnant glacial patterned ground on Thetford Heath, Suffolk.

Heathlands and acid grasslands

These are found on nutrient poor, acidic soils, generally formed by sandstones, sands and gravels, or associated with weathered granite or with peat.

Heathlands are dominated by colourful dwarf shrubs such as heather, cross-leaved heath and gorse, which are adapted to acidic soils and low levels of nutrients. They differ in their tolerance of water-logging so heaths are often mosaics of wet and dry communities, reflecting the porosity and permeability of the bedrock, or surface features such as relict glacial patterns.

Geological influences are also expressed regionally across climatic zones, with wet heathlands predominating in the Atlantic west, giving way to dry heaths and acid grasslands in the dry, more continental climate of the East Anglian Brecks.

Many of the rare and scarce species in these habitats are dependant on subtle, fine-scale aspects of the geology. Sundews, butterworts and bladderworts, in acid pools, deal with the low nitrogen levels by trapping and digesting insects. Sand lizards need sheltered sandy hollows and slopes for basking, and to warm their eggs. Solitary wasps, spiders and ant lions need sandy soils to construct their burrows and traps.

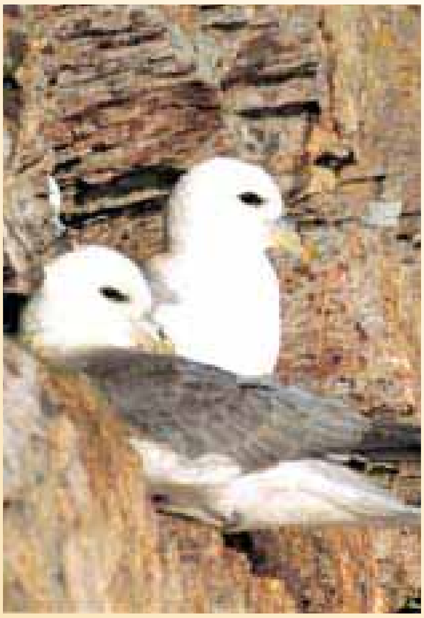
The mosaic of white beak-sedge and bog bean pick out fine scale patterns in these glacial sands at Thursley National Nature Reserve, Surrey.

Peter Wakely/English Nature 14,786

A recent survey of the nationally scarce shore dock increased the numbers of records by 30%. The survey focused on sites where water seepages emerged onto beaches from peri-glacial head deposits.
Peter Wakely/English Nature 18,105

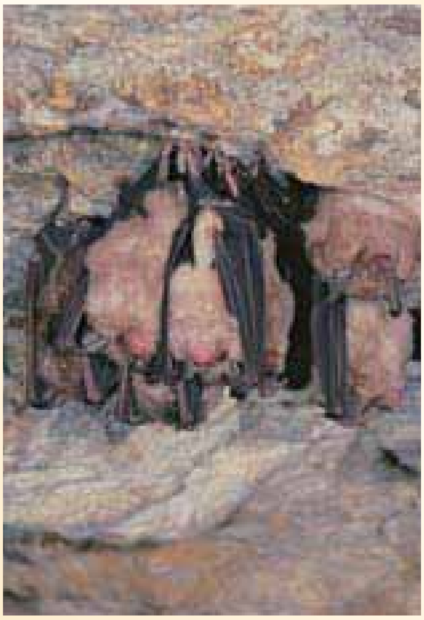
Rocks support life

Maritime cliffs and slopes have a specialised flora, including lichens and marine algae, and can be important for sea bird colonies. Where there are associated seepages and landslips other animals such as solitary wasps, bees, soldier-flies and craneflies can be found. These cliffs now represent some of England's least modified natural environments and support many animals that have lost their foothold inland.



Paul Glendell/English Nature 25,198

Cliffs are important for nesting sea birds, such as these fulmars.



Michael Hammett/English Nature 24,714

Greater horseshoe bats hibernate in limestone caves.

Pat Sargeant

Golden hair lichen on rocks in Cornwall.

Ecosystem management

Landscape ecologists, nature conservationists and land managers are now starting to adopt a holistic approach to managing ecosystems, to address and reverse problems caused by habitat loss, fragmentation and degradation. This approach acknowledges the important contribution of geodiversity in maintaining biodiversity: for instance, landscape patterns can provide vital clues to the location of former habitats, and soils can determine which areas are suitable for the re-creation of relevant habitats (English Nature 2004a). This should help maintain and manage our protected sites (English Nature 2003a) and reverse the dramatic declines in the populations and distribution of species and habitats (Townshend, Stace & Radley 2004). Several projects set up to apply this approach have drawn on ecological, geological and soil data and applied this across defined landscape areas to identify integrated environmental objectives for conservation, restoration and enhancement. Further work is needed to ensure that these projects incorporate objectives for the conservation of geodiversity, and apply the Ecosystem Approach (see Text Box page 49), ensuring full integration with social and economic objectives to achieve sustainable development.

China clay tips near St Austell.
Peter Wakely/English Nature 16,000

Putting back the wild heart of Cornwall

The St Austell china clay mining area was one of the most intensively mined in the UK, leaving a legacy of large volumes of tipped waste. This is now undergoing large-scale restoration as the basis for long-term habitat and landscape regeneration.

This is the biggest partnership project of its kind in Europe and has:

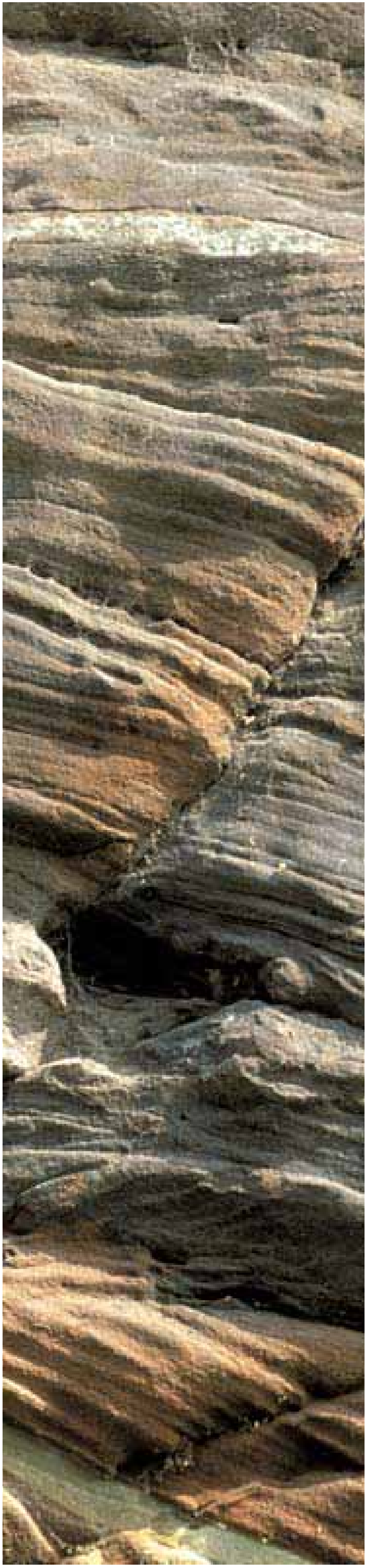
- Re-created 750 hectares of lowland heathland, meeting 12 per cent of the UK Biodiversity Action Plan target for heathland re-creation, and restored a further 1,066 hectares of SSSI heathland.
- Raised £2.4 m for restoration, including £1 m from industry and £1.3 m from the European Union Objective 5b programme and Heritage Lottery Fund, through English Nature's *Tomorrow's Heathland Heritage* Project.
- Worked with the socio-economic sectors to bring about joint agreement over the future of the clay mining area.
- Achieved significant public benefits through visual landscape improvements and increased public access.
- Engaged with industry and farmers, through regeneration initiatives and especially through local grazing and the establishment of specialist premium markets for 'heathland beef', in order to support long-term sustainable management of the restored sites.

The project has been successful because all interested groups worked together and applied a sustainable approach.

Paul Glendell/English Nature 24,832

Vibrant heather on restored china clay site at Penwithick.

Dee Cliffs, Farndon. Mick Murphy/English Nature



The Ecosystem Approach

The Convention on Biological Diversity (United Nations Environment Programme 1998) establishes 12 principles to deliver sustainable development under the 'Ecosystem Approach'.

- The objectives of management of land, water and living resources are a matter of societal choice.

- Management should be decentralised to the lowest appropriate level.

- The Ecosystem Approach should be undertaken at the appropriate spatial and temporal scales.

- Recognising the varying temporal scales and lag-effects that characterise ecosystem process, objectives for ecosystem management should be set for the long-term.

- Ecosystem managers should consider the effects (actual or potential) of their activities on adjacent and other ecosystems.

- Recognising potential gains from management, there is usually a need to understand and manage the ecosystem in an economic context. Any such ecosystem-management programme should:

  - reduce those market distortions that adversely affect biological diversity;
  - align incentives to promote biodiversity conservation and sustainable use; and
  - internalise costs and benefits in the given ecosystem to the extent feasible.

- Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the Ecosystem Approach.

- Ecosystems must be managed within the limits of their functioning.

- Management must recognise that change is inevitable.

- The Ecosystem Approach should seek the appropriate balance between, and integration of, conservation and use of biological diversity.

- The Ecosystem Approach should consider all forms of relevant information including scientific and indigenous and local knowledge, innovations and practices.

- The Ecosystem Approach should involve all relevant sectors of society and scientific disciplines.

Damaged soils in the Dark Peak, Derbyshire, are difficult to restore.

Moors for the Future

Extensive ploughed fields in the Vale of York.

Peter Roworth/English Nature

Soils in environmental management

Soil characteristics are strongly linked to geology, landform and landscape and directly influence biodiversity. Soils therefore have a central role in facilitating conservation and environmental management.

Good soil management is essential in the conservation, restoration, enhancement and re-creation of key habitats and landscapes. Soil science (understanding soil types, availability, quality and condition) is crucial to identifying appropriate locations for habitat restoration and re-creation schemes. It is also important in identifying appropriate management to achieve conservation objectives at a wider scale in the landscape.

Current research into soil resistance and resilience should provide information that will help us identify how far soils can change before they no longer support ecological processes. Experience in the Peak District suggests that some upland soils are too degraded to allow effective restoration of the soils and habitats. Inorganic elements of the soil are very difficult to replace and techniques for restoring soil organic matter, as used in agriculture, are not always appropriate for, or effective in, habitat restoration. For example, the use of organic waste and sludge does not replicate the previous organic soil profile and soil biodiversity.

Those complex issues are not well understood and further research is needed.

4.4 Sustainable communities

Although the financial security of a sustainable economy is an essential foundation to sustainable communities, environmental quality plays a significant role in determining where people choose to live and work (Park and others 2004). Environmental quality is fundamental to maintaining sustainable communities in the future (Office of the Deputy Prime Minister 2003a). Local landscapes, both rural and urban, are increasingly important as the setting for people's lives. Landscapes are also a great source of artistic inspiration, and offer opportunities for relaxation, recreation, education, health and enjoyment.

Although the physical forms of landscapes are central to quality of life and a 'sense of place', the landscape setting has subtle influences on people's experience of different parts of the country. Latitude influences day-length and warmth so that people in Northumberland have different perceptions of the seasons and the landscape than those in Kent. Local topography influences patterns of rainfall. People living along rivers might appreciate the flow and pattern of the water, but may feel vulnerable to flooding. The warming effect of the Gulf Stream allows gardeners on the west coast to grow palms, but the storms crossing the Atlantic makes them more aware of the inherent power of the ocean. Those on the Yorkshire coast also experience the power of the sea as the soft sediments of the Holderness coast erode away.

All these factors combine to provide the physical context to our everyday life, influencing where people live and work, what they do from day-to-day, and the way they think about, value and respect their environment. Landscape is a key component of community wellbeing, linking present-day and past social values and providing the visual aesthetic and inspirational setting in which society lives, works and relaxes (Council of Europe 2000).

Pat Sargeant

Giant echiums thrive in gardens in the balmy climate of the south west.

Bridgnorth – living on a floodplain has obvious risks.

Paul Glendell/English Nature 25,072

Pat Sargeant

Granite blocks in a Cornish dry-stone wall.

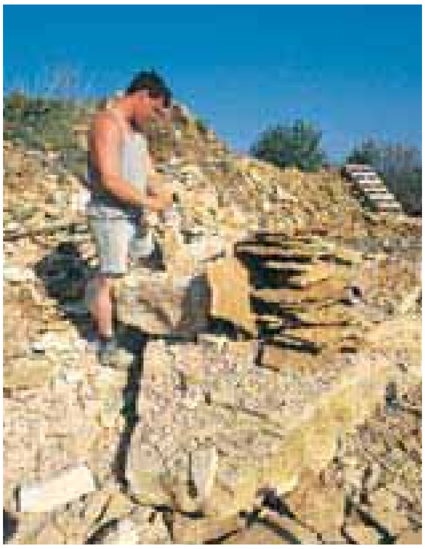
4.4.1 A sense of place

The patterns of settlement and land use with their historical and cultural associations, together with distinctive local building stones and styles, convey a strong 'sense of place' that is an important element of quality of life. This creates and influences landscape character.

A key element of environmental quality, whether historical or aesthetic, is the variation in colour, texture and form across the geological landscape of England. Local soils revealed by ploughing, colour the rural landscape. Local stones, bricks and building styles, give colour and character to the buildings in our villages, towns and cities and to the barns and walls of rural landscapes. The honey-coloured limestone of Cotswold villages contrasts with the grey, flint-faced churches of East Anglia, and the red brick buildings of the Staffordshire Potteries. Roofing materials vary in colour and texture, from Delabole Slates in the south west to Collyweston Slates in Northamptonshire, and are laid in different patterns according to their thickness and size. The slate fences and stone hedge banks of Devon have a very different style to the dry-stone walls of the Yorkshire Dales.

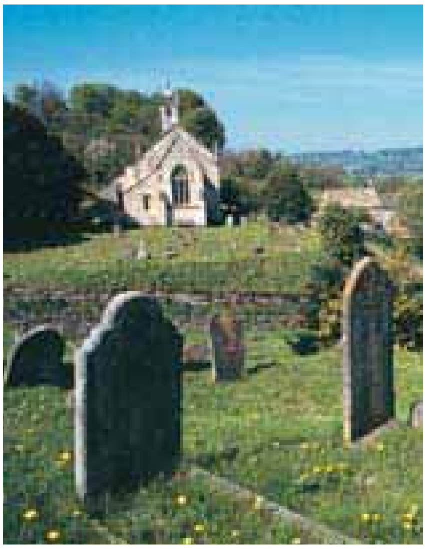
Peter Wakely/English Nature 19,324

Picturesque village in the Cotswolds, built with Jurassic limestones.



Peter Wakely/English Nature 20,298

Stone tiles used for roofing in the Cotswolds.



Peter Wakely/English Nature 19,323

Churchyard, stone walls and gravestones in local stone.

Building styles

Mick Murphy/English Nature

Peterborough Cathedral. The tombs and memorials in Cathedrals used materials from further afield including marbles from Dorset, Belgium and Italy.

Stone was not widely used until the Romans introduced mortar and stone-dressing techniques to replace dry-stone walling. Initially it was transported by hand and horse, so material was drawn from local quarries, close to the buildings. Thus early stone buildings, whether domestic or prestigious, reflect the local sources, both through their differences in shape, texture and colour and in the structural characteristics of the stone (Maxwell 2002). For example, Durham Cathedral is built from locally quarried yellow sandstones, has a Cumbrian Slate roof and ornamental Frosterley Marble. Peterborough Cathedral is built from locally quarried Lincolnshire Limestone with decorative details in Alwalton Marble and chalk from Cambridgeshire.

With the advent of rail transport, building materials – especially bricks – could be transported cheaply and used in everyday houses and buildings. The character of bricks depends on the composition of the clays used to make them, the additives and methods of firing; most red bricks are from the Jurassic Oxford Clay, London's yellow bricks are from the 'brickearth' glacial loess of south east England, whilst Staffordshire Blue brick is from the iron-rich Etruria Marls of the West Midlands (Clifton-Taylor 1987).

Philip Brashaw/LDA Design

Clair College, Cambridge, shows the different types of brick used in buildings.

Railway stations show how brick became a ubiquitous building material using standard templates. The progressive influx of decorative building stones is charted in the imported headstones and monuments of local cemeteries. Portland Stone was used extensively in London and other major cities. More expensive decorative stone, often imported from overseas, was used for high status buildings. Many of these include fascinating rock types, structures and fossils, especially shells, corals and sea lilies. In some areas, fossils such as ammonites are deliberately incorporated into buildings, or inspire their design.

Fossil ammonites – here used in a Dorset wall – inspired the Regency Period's 'Ammonite Order' style of architecture. Keith Duff/English Nature

Colin Prosser/English Nature

The world's first dinosaur park, opened in 1854, in Crystal Palace Park, with concrete dinosaurs, such as this *Megalosaurus*.

Urban landscapes

Economic growth and development, including the continued exploitation of geological resources, has brought fundamental change to some landscapes. This is particularly true in coal mining and quarrying areas and in urban settings. Even here, the landscape still preserves traces of its geological history, and geodiversity plays an important part in urban geography. Many of our larger cities and towns were founded close to mineral resources, especially coal, and have strong cultural ties to their industrial past. Rock outcrops were ideal sites for castles. Most towns and cities still reflect the underlying topography, geomorphology and landscape including their relationships with agricultural land, rivers, estuaries and the coast. Roads can follow the sinuous courses of old waterways, now culverted, and many urban parks, gardens and green spaces are former quarries or areas of land that are particularly difficult to develop due to underlying geology or geomorphology. Brownfield land, including sites linked to past mineral extraction, can also be an important resource for experiencing different aspects of geodiversity, as well as biodiversity. They may include rock exposures or spoil heaps which can provide reservoirs of fossil material or minerals. The rehabilitation of these sites can enhance the quality of life in urban areas (Damigos & Kaliampakos 2003), providing opportunities for habitat enhancement and access for a range of recreational activities.

Lister Park in Bradford

Lister Park in Bradford was restored with a grant of £3.2 m from the Heritage Lottery Fund's Public Parks Initiative. The views of 15,000 local people contributed to the project, which eventually included restoration of the boating lake and pavilion and the creation of an Indian style Murghal garden.

Geology trail through the re-landscaped botanical garden in Lister Park. Bradford Council

Pat Sargeant

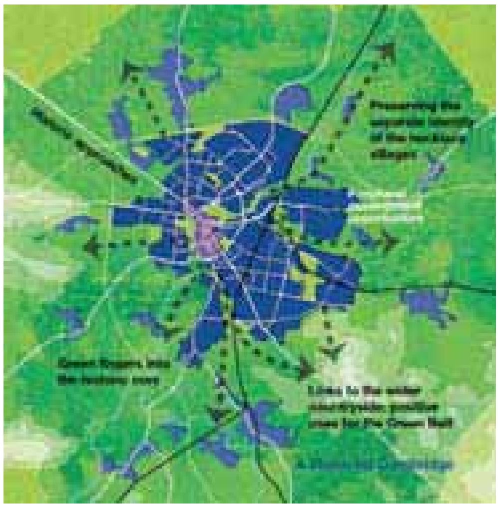
The Eden Project is an innovative tourist attraction developed in a former China clay pit, Cornwall.

Eighty per cent of people live in urban areas, so these sites offer great potential for making people aware of geology in the places where they live and work (Bennett and others 1996). This is now being realised in many places through town trail leaflets and guided walks, where these assets can bring significant community and socio-economic benefits. The importance of working with the landscape and natural processes, to deliver sustainable development in urban townscapes and the countryside ‘in and around towns’, is increasingly recognised both regionally and nationally.

The countryside in and around towns

The countryside in and around towns (Countryside Agency and Groundwork 2005) serves as a bridge to the countryside and a gateway to the town, a ‘health centre’ and classroom, a productive landscape, a cultural legacy and a nature reserve. It can be an engine for restoration, a centre for recycling and renewable energy and a setting for sustainable living to improve the quality of life for millions of people. It inspires urban living that is connected to nature, to the countryside and reflects our responsibilities to the wider environment.

With a strong strategic planning framework, the skills of land managers and the involvement of local communities, the countryside in and around towns can incorporate both new and regenerated landscapes, an abundance of diverse and accessible green spaces, including country parks, community woodlands, nature reserves and green corridors.



A Vision for Cambridge prepared as part of the Cambridge Green Belt Study. LDA Design and South Cambridge District Council

Cambridge Green Belt Study

Cambridge City Council carried out the Green Belt Study to inform plans for future development of the city, particularly the need for 22,000 houses in the sub-region by 2016. It considered landscape and townscape character and the functional, visual and historical relationship between Cambridge and its landscape setting. This included views in and out of the city, particularly those framing historic landmarks and on the approaches to the historical centre. It also considered the distribution of green space and the setting and identity of the peripheral villages in order to identify the qualities to be safeguarded. The final stage of the project established a vision for the city which seeks to maintain these special qualities.

The green setting for King’s College Chapel.

Philip Bradshaw/LDA Design

4.4.2 Artistic and spiritual inspiration

The aesthetic qualities of rocks, and the landforms and landscapes formed by them, have inspired many writers, poets, musicians and artists. The forms, colours and textures of rocks and landscapes are enriched by ephemeral changes of light, shade and weather conditions. These qualities create a sense of openness, tranquility, and in some situations, provide a 'wilderness' experience. Geodiversity has influenced traditional narratives, including legends, folklore and folk music and it inspires fine art and high culture.

Landscapes inspire writers, poets, musicians and artists. South Downs, East Sussex.

Mick Murphy/English Nature

Early man carved and painted animals on cave walls, made rock engravings in prominent sites and used stone to create monuments such as Stonehenge and Avebury. Stone sculptures, inspired by the nature of the rock as much as by their subject matter, have been a significant part of our artistic heritage ever since. In recent decades this work was continued by artists such as Barbara Hepworth, whose sculptures were inspired by Cornish landscapes. Further examples include modern works where stone and other natural materials are used in landscape settings, and community art projects such as that at Tout Quarry on Portland.

Val Corbett

'Water cut' by Mary Bourne, sculpted from Salterwath Limestone.
One of 10 specially commissioned sculptures in the Eden Valley.

Rock art

Rock art provides an interesting link between geology, history and culture from prehistory to the present. It covers a variety of art forms including paintings and carvings on rocks, sculpture using rocks and modern contemporary art. Examples include:

- Cresswell Crags – known since Victorian times as a place of Ice Age human occupation although Britain's first cave art was only discovered here in 2003. The engravings, which include aurochs, deer, bear and ibis, are 12,800 years old.

- The Folkton Drums – cylinders of local chalk decorated with incised geometric designs, were grave offerings for a 12-year-old child, found in a round barrow at Folkton, in Yorkshire (Middleton and others 2004). The motifs resemble Later Neolithic Grooved Ware pottery, the decoration of Beaker pottery and some Early Bronze Age gold work, dating them to approximately 2500–2000BC.

Bronze plaque depicting fossil life at the Ercall nature reserve.

Shropshire Wildlife Trust

Bison rock carving at Cresswell Crags.
Ian Wall/Cresswell Heritage Trust

Wooden trilobite sculpture on the Wren's Nest National Nature Reserve, Dudley.
Jonathan Larwood/English Nature

Crystals and fossils are regarded as beautiful objects and curios, and awakened the interest of 18th and 19th century collectors to the significance of geology. Gemstones and other natural products such as jet and amber are used for jewellery. Some fossils, rock formations and landscapes have been the subject of mythology and folklore (Bassett 1982), for example the 'Devils punchbowl' in Surrey, and the 'Witches causeway' at Filey Brigg.

Geomythology

Ammonites were originally named for their resemblance to the ram's horns of the Greek God Jupiter Ammon. But they have a range of English names reflecting different local legends.

In Whitby, Yorkshire, they are called snakestones and were thought to be coiled snakes turned into stone by St Hilda. At Keynsham, near Bristol, they were also thought to be snakes turned to stone, this time by St Keyna, whilst in Dorset and Wiltshire large ammonites in the Portland Stone were called conger eels.

Belemnites, found in Jurassic and Cretaceous rocks across England, were thought to be darts thrown down from heaven during thunderstorms, whilst the fossil oyster *Gryphaea,* also from Jurassic rocks, is called the Devil's toenail, because of its curved toenail-like appearance.

Snakestones – snake heads were carved onto ammonite fossils to reinforce the legend.

Graham Pickles/Whitby Museum

English paintings have represented geodiversity, in the form of local landscapes, for hundreds of years. Originally used as the backdrop for religious, mythological or historical stories, it was not until the 18th century that landscapes were painted as subjects in their own right. The landscape paintings of Constable retain iconic significance in the history of art. Since then landscape art has continued to diversify, with places like Wapping on the Thames, and St Ives in Cornwall, attracting influential communities of landscape artists inspired by the drama and variety of their settings. More recently landscape has become the focus for photographers such as Faye Godwin and Colin Baxter.

Lyme Regis Museum

Reaping the Wheat in the Great Landslip, 25 August 1840, painting by W Dawson.

Musicians have similarly been inspired by our varied landscapes, with links between geodiversity and music found in classical, popular and folk music. Edward Elgar drew his inspiration from the Malvern Hills, and the Suffolk coast inspired Benjamin Britten. Mike Oldfield composed Hergest Ridge, and Vera Lynn sang about the White Cliffs of Dover. The cultural significance of rocks and landscapes is also highlighted in oral tradition, for example in traditional folksongs such as ‘Byker Hill’ based on life in mining and quarrying communities.

Landscape has been celebrated in literature since the Middle Ages. Examples include Langland’s lyric poem *Piers Plowman*, the settings of many of Shakespeare’s plays, Hardy’s Wessex novels, Houseman’s *The Shropshire Lad*, the Lake District group of poets and the works of Auden inspired by the North Pennines lead-mining landscapes. There is a recent resurgence in modern popular science writing with a geological theme, such as *The Floating Egg* (Osbourne 1998), *The Map That Changed the World* (Winchester 2001) and *The Hidden Landscape* (Fortey 1993).

The world of television and film brings geodiversity to a wider audience. Recent examples include Steven Spielberg’s film *Jurassic Park*, Ronald Donaldson’s *Dante’s Peak*, the *Earth Story* TV series, *Talking Landscapes* presented by Professor Aubrey Manning and *Walking with Dinosaurs* presented by Tom Haines. Specialist television channels such as National Geographic, Discovery and UK Horizons also broadcast programmes that feature geodiversity. Most recently, David Dimbleby’s *A picture of Britain* has explored the cultural and inspirational links between landscape and art, the programme being linked to a major landscape retrospective at Tate Britain.

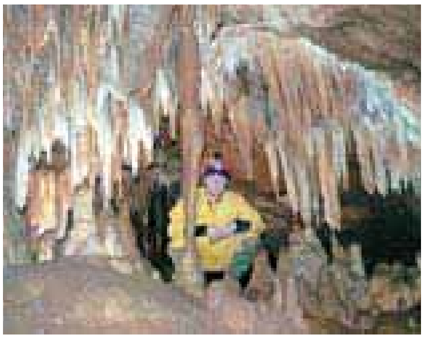

Peter Wakely/English Nature 17,148

Sailing is popular on inshore waters and on our estuaries and coast.

4.4.3 Active communities

Good health is an essential element of quality of life. Geodiversity, along with biodiversity, can play a role in promoting both active and informal recreation to reduce health problems such as obesity and heart disease. The cost of physical inactivity has been estimated at £8.1 billion a year. Of this, £5.4 billion is lost earnings due to sickness and absence, £1 billion is earnings lost due to premature mortality and £1.7 billion is direct health costs for the National Health Service (Pretty and others 2003).

Geodiversity provides opportunities to be active, to relax and enjoy the view, spend time with friends and family, meet new people and have fun. Exercising outdoors – including walking and conservation work – is good for your health and improves quality of life through spiritual and mental refreshment (Seymoor 2003). Walking and gardening have both been found to be a more effective and lower-cost way of tackling heart disease than prescription medicines or joining a gym (walking one mile a day reduces the risk of coronary heart disease by 50 per cent, (Bird 2003)). Walking festivals are increasingly popular and some of these offer guided geology trails.

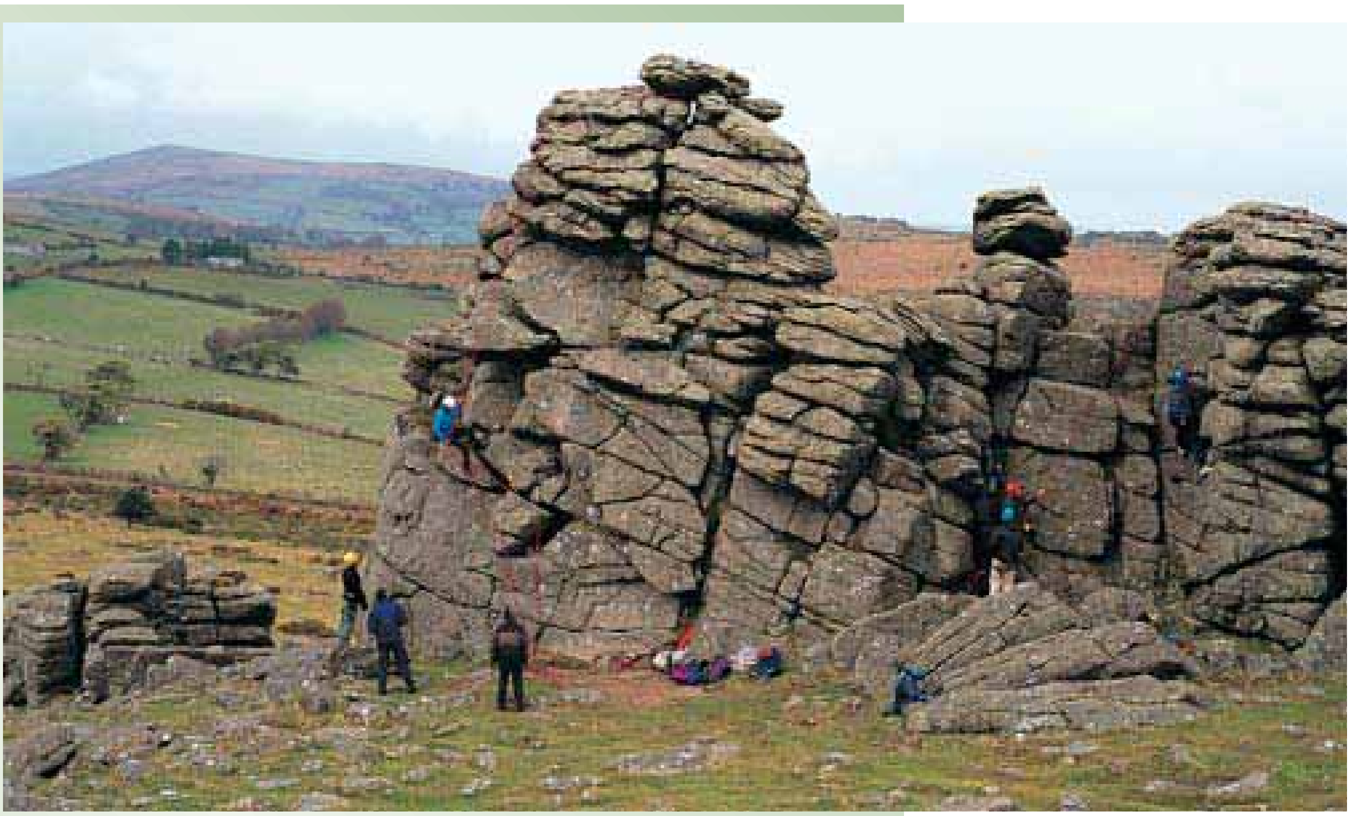

David Kestell

Geodiversity provides the setting for healthy outdoor activities.

Diverse landscapes, whether rural or the countryside in and around towns, encourage healthy exercise including walking, running and cycling. Hill country and coasts attract many walkers. Natural rock exposures and quarry faces attract climbers and abseilers. People also enjoy caving and potholing, and 'show caves' allow a wide range of people access to the underground world. Rivers and abandoned clay and gravel pits are used for canoeing, rowing, rafting and other adventurous water sports as well for fishing and informal recreation. Such outdoor activity is important for raising levels of fitness, developing and maintaining physical balance and co-ordination, and developing judgement of risks.

Sail boat on Fowey Estuary.


Pat Sargeant



Peter Wakely/English Nature 24,239

Climbers on Hound Tor, Devon.

Choosing activity

The Department of Health's 2005 report *Choosing Activity* commits the Government to: "ensuring that people in all parts of society get the information they need to understand the links between activity and better health and where the opportunities exist in daily life to be active". This includes "continuing to make our public spaces and the countryside more accessible and attractive".

The 2005 *Health Concordat* aims to develop innovative projects with the health sector to demonstrate the role of the outdoors in delivering health and wellbeing. More people are to be encouraged and motivated to have contact with, and get more enjoyment from, attractive landscapes and open spaces, such as restored mineral workings and urban green spaces.

Canoeing, Upper Fowey Estuary, Cornwall. Pat Sargeant

Walkers on a coastal path.

Pat Sargeant

Gloucestershire Geoconservation Trust

Children finding out about geology with the help of an interpretation board. Rolling Bank Quarry, Cleeve Hill.

4.4.4 Understanding and enjoyment

The study of geology can be inspirational: it is a hands-on subject, accessible to people of all ages and at many levels. Learning about geodiversity develops scientific, observational and analytical skills. It can encompass the history and philosophy of science, ideas and theories, and it provides a powerful conceptual model for understanding science, society and the world. It can provide the motivation to develop skills in scientific analysis, mathematics and data handling (English Nature 2003c). Getting out in the field, to experience and study geology first hand in the wider landscape, can awaken interest through exploration and observation, bringing theory to life and widening horizons and aspirations. Field work also engenders positive attitudes towards conservation and the environment (Hawley 1998) and helps people to get fit!

Geology in education (English Nature 2003c)

Despite the value of geology for developing a range of skills, the numbers of pupils studying geology has declined steadily over the last 10 years. The National Curriculum has reduced its coverage from about 12 per cent of the science allocation, initially as a defined Earth Heritage module, to 4.4 per cent dispersed to the other sciences.

Geology is covered as an element of the core science in Key Stages 1–2 covering ages 5–11 and is usually an element of geography at GCSE, AS and A level. Geology is also available as a stand alone subject at GCSE, AS and A level, but the availability of these options has declined.

The need for field work may discourage schools offering geology, due to the lack of expertise, increasing health and safety concerns and the costs of transport, insurance and staff cover. Primary schools with their multidisciplinary approach find it easier to arrange fieldwork, whilst in secondary education, timetabling difficulties restrict opportunities.

The number of Universities and Colleges offering geological subjects has also declined over recent years. Only a few of these offer modules on geoconservation, for example Birkbeck College, University of London has an MSc module on Earth Heritage Conservation. A similar loss is seen in soil science related subjects with departments decreasing in size or amalgamating with others.

In October 2004 the All-Party Parliamentary Group for Earth Sciences confirmed the shortage of Earth scientists for employment in aggregates, minerals, petroleum, environment and elsewhere. These shortages are likely to increase as geology declines in mainstream education.

Peter Oliver

‘Rock and fossil roadshows’ are increasingly popular.

Enthusing a new generation of young geologists – children in trilobite masks enjoying a rock and fossil roadshow at Stroud Museum.
Gloucestershire Geoconservation Trust

Promoting educational use of geological sites in Devon

An *Educational Register of Geological Sites in Devon* (Devon County Council 2002) has been assembled by English Nature, the Devon Regionally Important Geological and geomorphological Sites (RIGS) group and Devon County Council to help schools, colleges and universities plan their geological fieldwork. The register explains the geological history of the county, provides maps, information and pictures of 79 sites, and gives suggestions for practical activities at each location. This register was funded by English Nature and the Curry Fund of the Geologists’ Association.

The *Educational Register* is now complemented by a *Geodiversity Audit of Active Aggregate Quarries in Devon* (Nicholas 2004). The audit draws together information on 16 working quarries in the county, presented as site reports, which include annotated photographs of key features at each quarry. The project was funded by the Aggregates Levy Sustainability Fund via the Mineral Industry Sustainable Technology Programme.

View of Venn quarry in Devon. One of the sites on Devon’s ‘Geodiversity Audit of Active Aggregate Quarries’. Clive Nicholas/David Roche GeoConsulting

Sedgwick Museum

Above and below. Important fossil finds are revealed at an excavation at Mepal, Cambridgeshire.

Crocodile in the Fens

In 2001, two local collectors discovered some important fossils on land being developed for a fish farm at Mepal, near Ely. These remains are 140 million years old and a rare fossil find in this part of Cambridgeshire.

The fossils included fragmentary remains of a crocodile, initially identified as a *Steneosaurus*, and the scattered remains of an ichthyosaur *Brachypterygius* sp. together with the teeth of sharks and a ray, as well as fish scales and jaw fragments. These were excavated by the Sedgwick Museum, with the help of the finders, and the bones were donated to the Museum by the owners and developers of the land.

See the Sedgwick Museum website at: www.sedgwickmuseum.org/research/Mepal_Ichthyosaur.pdf [Accessed 2 March 2005].

Scarborough Museums & Gallery

This model plesiosaur was made by people with learning difficulties to decorate the wall of their day care centre.

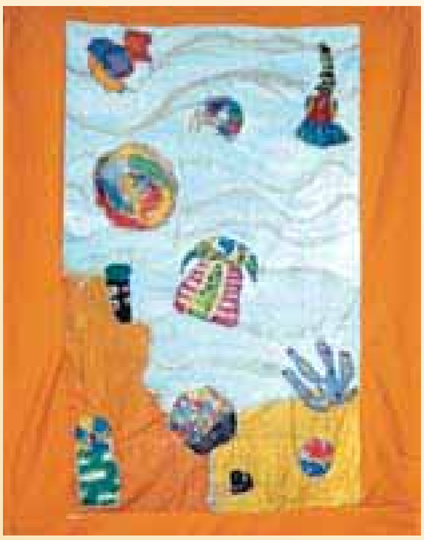
Dinosaur Coast Project

The Jurassic geology and fossils of the Yorkshire Coast (including the Scarborough and Whitby Museum collections) have inspired 32 different community projects through the Heritage Lottery Funded Dinosaur Coast Project. The projects have reached local schools, play schemes in deprived areas, children with special needs and adults with learning difficulties. They have included a sensory trail and a dry-stone wall incorporating a geological timeline and fossils.

Graham Worton

Children create imaginative works of art based on their fossil heritage.

Over 12,000 people have taken part in Dinosaur Coast activities over the last three years, establishing a strong basis of support for geodiversity in the area. The next step is the redevelopment of the Scarborough Rotunda museum as the gateway to the Dinosaur Coast.



Graham Worton

Children's quilt art created as part of the Dudley Waves Project.

Making waves

The Waves Project in Dudley, West Midlands, aimed to inspire children about their world-renowned geological heritage and to use their imaginations to see the area as it was many millions of years ago. Working with artists, children produced 'geoart' inspired by objects contained in specially designed wooden boxes – carved with images of local fossils – and visited the Wren's Nest National Nature Reserve which is rich in fossils. The finished works were brought back to Dudley Museum for display alongside the fossils.

5 Conserving and monitoring geodiversity

Geodiversity is important to sustainable development and must be carefully managed. This includes the conservation of geological sites, the conservation and restoration of natural geological processes, and the sustainable management of landscapes, land and soils. This section reviews the conservation of the different elements of geodiversity, the methods used to monitor them and their condition.

5.1 Geology and geomorphology

Sites of Special Scientific Interest

Nationallly important geological and geomorphological sites are protected as Sites of Special Scientific Interest (SSSIs). At present there are 1,240 SSSIs in England with a notified geological or geomorphological interest, representing approximately one-third of the existing SSSI coverage. These sites were selected through the Geological Conservation Review (GCR), a site-based audit of Great Britain's geological and geomorphological resource, undertaken between 1977 and 1990 (Ellis and others 1996). It provides a scientifically robust, systematic record of nationally important sites covering the complete range of geological interest, natural processes and landforms. It is the largest assessment of its kind and there is still no other audit of this quality elsewhere in the world.

The Geological Conservation Review

The review identified over 3,000 sites in Great Britain, selected against one or more of three criteria:

1 International geological importance.

2 Scientific importance for exceptional features (ie rare, unique or archetypal features).

3 National importance, representing an aspect of geology that is fundamental to understanding Britain's geological history.

The sites selected range from natural outcrops and coastal cliffs to artificial sites such as quarries, pits, and road and rail cuttings. They are of national scientific importance. Considered together they have wider significance as part of a coherent and dynamic national network, representing our current understanding of geology. This network, from which the SSSIs are drawn, remains the national basis for site-based geological and geomorphological conservation in England.

Mam Tor, part of the Castleton SSSI, Derbyshire.
Mick Murphy/English Nature

The Wren's Nest NNR – an ancient Silurian reef in a modern urban landscape, Dudley.

National Nature Reserves

National Nature Reserves (NNRs) are among the best SSSIs, managed to conserve their habitats and geology and to provide special opportunities for appreciation and scientific study. A small number of NNRs are specifically designated for their geology. The best known of these is the Wren's Nest NNR which is designated for its internationally important Silurian limestones and fossil reefs. Many NNRs have both geological and biological interests. For example, the Axmouth to Lyme Regis Undercliffs in East Devon is designated for its Jurassic geology and palaeontology, its vast coastal landslips and its cliff vegetation, which is strongly controlled by active landslips. The geology, coastal geomorphology and habitats are intimately linked. Even where there is no formal geological designation, all NNRs have strong links to their underlying geodiversity.

The famous trilobite *Calymene blumenbachii*, known as the 'Dudley Bug' from the Wren's Nest NNR.

International sites

The Dorset and East Devon Coast is a natural World Heritage Site, inscribed in 2001 by the United Nations Education, Scientific and Cultural Organisation (UNESCO), for its global importance to geology. It is currently the only natural World Heritage Site in England. This 150 km stretch of coast exposes 225 million years of geological history, and from west to east provides a 'walk through time'.

The North Pennines AONB and the Abberley and Malvern Hills became European Geoparks in 2003. This label, endorsed by UNESCO, recognises the international importance of an area for its outstanding geology, and the value of geodiversity in achieving sustainable development. In April 2004, the two sites became founder members of the UNESCO Global Geoparks Network. New networks of geoparks are being established in Australia, Africa, Asia and North and South America.

High Force in the North Pennines AONB European Geopark.

Geomorphologically important features, such as limestone pavement and coastal dune systems and salt marsh, are also essential components of many internationally important ecosystems which are protected as Special Protection Areas, Special Areas of Conservation or Ramsar sites.

At an international level, sites of "first class importance to global geology…" will also be identified in a systematic global inventory through the Global Geosites Programme. This was set up by the International Union for Geological Sciences (Wimbledon and others 2002) and is co-ordinated in Europe by the European Association for the Conservation of Earth Heritage (ProGEO).

Local sites

There are many sites with features of regional and local interest. Over the last 15 years, local voluntary geoconservation groups have made audits of geological sites and features within their areas and have selected key sites for protection as Regionally Important Geological and geomorphological Sites (RIGS). These are important, regionally or locally, for scientific and research purposes, but they are also selected on the basis of educational value and historical and aesthetic interest. There are currently about 2,000 RIGS, but this work is ongoing and the total number of sites could reach 4,000 in England.

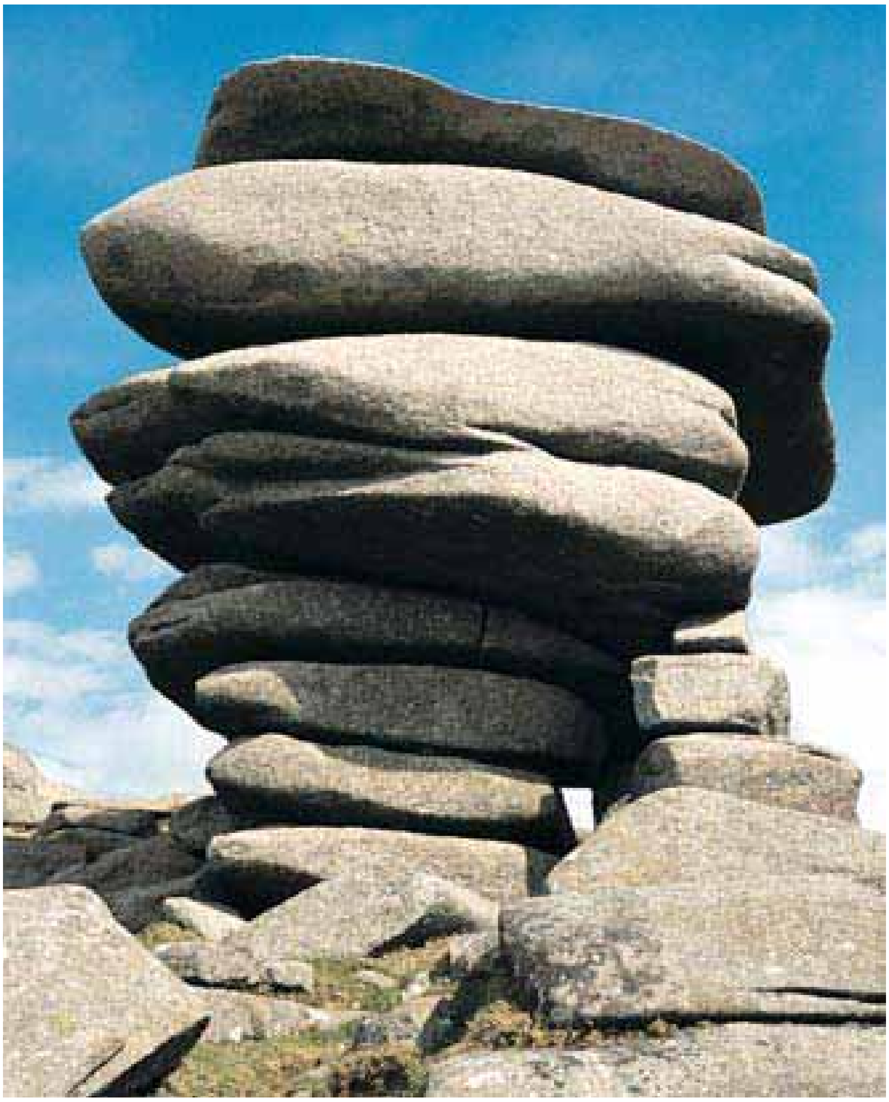
Flaxley Quarry RIGS, before (above) and after (below) restoration by the local Geoconservation Group.
Gloucestershire Geoconservation Trust

Local geoconservation groups

Local geoconservation groups include The Geology Trusts, RIGS Groups and societies attached to museums as well as other institutions, such as The Wildlife Trusts. They undertake much of the work outside protected sites. Their work includes selecting, nominating and managing RIGS, preparing Local Geodiversity Action Plans, and raising the profile of geoconservation with other organisations. They consult, inform and involve a wide range of stakeholders, interest groups, organisations and the public and promote a professional approach to geoconservation. This includes running training courses, exchanging best practice and staff expertise and expanding and developing the volunteer base. The voluntary geological movement is still relatively new and has not yet attained the level of support or awareness achieved by The Wildlife Trusts. However, the movement is growing rapidly and new funding sources, such as the Aggregates Levy Sustainability Fund, are providing new momentum.

Cornwall RIGS Logo

Cornwall RIGS take their motif from a famous local rock formation, the Cheesewring.



Pat Sargeant

Local Geodiversity Action Plans

Local Geodiversity Action Plans (LGAPs), modelled on Biodiversity Action Plans, are being developed to provide a sustainable framework for regional and local conservation of geodiversity. These are prepared for defined areas, such as counties, Areas of Outstanding Natural Beauty, and National Parks. They involve a wide range of partners from the local community, conservation, local government, business, industry, tourism and education to ensure local support for, and endorsement of, their aims and objectives. LGAPs establish objectives and targets for audit, conservation, management, education and communication as well as the influencing of local plans and policies and the securing of resources to implement the plan.

Cheshire Local Geodiversity Action Plan

The *Cheshire Region Local Geodiversity Action Plan* (LGAP) was prepared by the University College Cheshire, working with the Cheshire RIGS Group and Cheshire County Council, in partnership with 20 other organisations.

The LGAP aims to maintain and improve the wellbeing of Cheshire by safeguarding the geology, geomorphology, soils and landscapes of the region. Its objectives cover audits, policy formulation, raising awareness, increasing participation and creating a monitoring and review strategy.

The audits cover sites, existing geodiversity information, and the skills and resources of existing and potential partners. Activities have been specifically targeted at professional bodies, conservation practitioners, site managers, landowners, the education sector and the general public, in order to increase community and business participation in the conservation of identified geodiversity sites.

Since the launch in 2003, more organisations have joined the partnership, including industrial companies. The objectives are currently progressing well and geodiversity targets and actions are being woven successfully into other relevant strategies such as the Community Strategy.

The Cheshire region Geodiversity Action Plan (CrGAP) was launched in 2003 and has set a high standard for LGAP development and delivery.

LGAPs all share a common philosophy and approach to the conservation and enhancement of geodiversity, but they cover a range of administrative areas and take different approaches, according to the priorities of the partner organisations. English Nature has published guidance on the preparation of LGAPs (Burek and Potter 2004, 2005). LGAPS have provided new impetus for the conservation of geodiversity and have proved a successful route to gaining more resources from a range of sources.

Mick Murphy/English Nature

Accessing funds for geodiversity

The North Pennines AONB is a European Geopark. The AONB Partnership has secured significant resources for the implementation of its Local Geodiversity Action Plan from a wide range of sources with a variety of environmental, social and economic objectives. This demonstrates the potential for accessing funds, although there are significant costs involved in preparing and submitting the bids and securing match funding.

Sustainable Tourism in Protected Areas (STIPA). Funding of €200,000 (approx. £135,000) has been obtained through an Interreg IIIc / One Northeast funded initiative called TouriSME, which aims to support Small and Medium Enterprise development and sustainable tourism. The AONB Partnership will carry out market research, establish and promote a network of 'Geopark B&Bs', with a visitor payback scheme and geological trails, and support other local tourism initiatives.

Heritage Lottery Fund (HLF) funding for LGAP implementation. The AONB partnership has received a grant of £416,000 over four years to implement many aspects of the Geodiversity Action Plan. This project will fund a Geodiversity Officer and activities such as site-based interpretation and trails, children's geology clubs, training events, geology festivals, education resource materials, walks, mini-bus guided tours and training for local site guides. Also included is the development of a Geopark cycle trail, with match-funding coming from the Wear Valley Neighbourhood Renewal Fund. It will also support cycle infrastructure development at B&Bs and attractions.

Transnational Leader+ programme. Funding of approximately €35,000 (£24,000) is being sought from this programme for a joint project with 12 partner Geoparks. It will involve the development of common display and promotional material, geological trails and other geotourism work.

Monitoring geological sites

Knowledge of the condition of geological resources relies on the assessment of nationally important geological sites. Government has set a Public Service Agreement (PSA) target for 95 per cent of SSSIs to be in a favourable condition, or under favourable management, by 2010. In the first six-year cycle of assessment, completed in 2003 (English Nature 2003a), 83 per cent, by number, of English geological and geomorphological sites met this target.

Tregargus Fluorite granite.

John Arum

Welton le Wold SSSI, Lincolnshire. Site being restored to favourable condition using heavy machinery.

Assessing the condition of geological sites

English Nature has established effective systems for monitoring geological and geomorphological SSSIs through regular condition assessments (English Nature 1999, Murphy 2001, Prosser, Murphy and Larwood 2006). These are based on the Common Standards monitoring and reporting initiative, established by the country statutory conservation agencies, co-ordinated by the Joint Nature Conservation Committee (JNCC 1998). This uses criteria derived from the Geological Conservation Review (GCR), translated into individual 'Conservation Objectives' for each site.

Monitoring results are recorded against individual GCR features. This is because SSSIs often contain several GCR features and some features cross several SSSIs. Many important geological sites are so small that figures stated by area cannot accurately represent the state of the resource, so results are presented by number of sites. There are six condition categories: favourable, unfavourable recovering, unfavourable no change, unfavourable declining, part destroyed and destroyed.

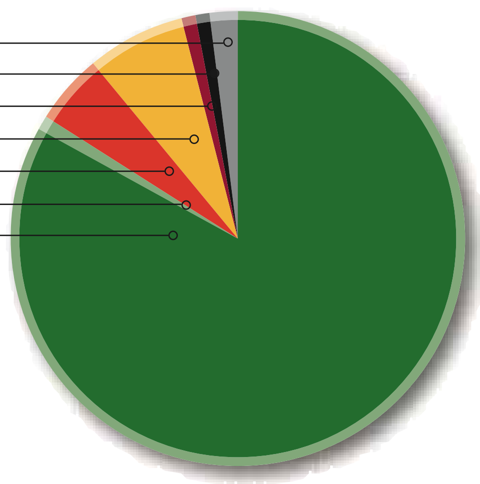
A geological site is in favourable condition if the features of interest are exposed, or can be easily re-exposed, by small-scale digging or vegetation clearance. This would involve one or two people using hand tools for less than half a day, without resort to heavy machinery. The ideal may be 100 per cent exposure of the interest features but to achieve this is frequently impractical. A much smaller exposure may be sufficient if it is well-maintained, displays the key geological features and can be used for research purposes.

The three unfavourable categories apply to sites where the interest features are present, but are obscured, typically by dense vegetation or rock debris, and are not available for study. Most unfavourable geological sites, being static, fall into the 'unfavourable no change' and 'unfavourable declining' categories. The 'unfavourable recovering' category applies mainly to active geomorphological sites where remedial action has reversed the decline and the processes which underlie the interest features are recovering. The 'part destroyed' and 'destroyed' categories apply to sites where the interest features have been partly or completely removed and no remedial action is possible.

Sites meet the Public Services Agreement target if they are favourable, or if they are in 'unfavourable recovering' condition, with positive management in place to address all the problems.

Welton le Wold SSSI, Lincolnshire. This site is in unfavourable declining condition as key features are obscured and the site is continuing to deteriorate. Mick Murphy/English Nature

Number of GCR sites



This excellent record has largely been achieved through English Nature's Face Lift project, which has directed about £470,000 over the last six years to restore more than 260 SSSIs. Enhancement work has included vegetation clearance, scree and rubbish removal and re-excavation of geological sections, as well as the provision of on-site information, improved safety and better access for visitors. However, without a long-term commitment to ongoing management, many favourable sites will degrade and decline. This accounts for the fact that, despite further restoration work under Face Lift, the overall figure for favourable sites in 2005 still stands at 83 per cent. English Nature has addressed this problem by launching the Geological Enhancement Scheme, to assist landowners and managers with the costs of ongoing management to maintain favourable condition.

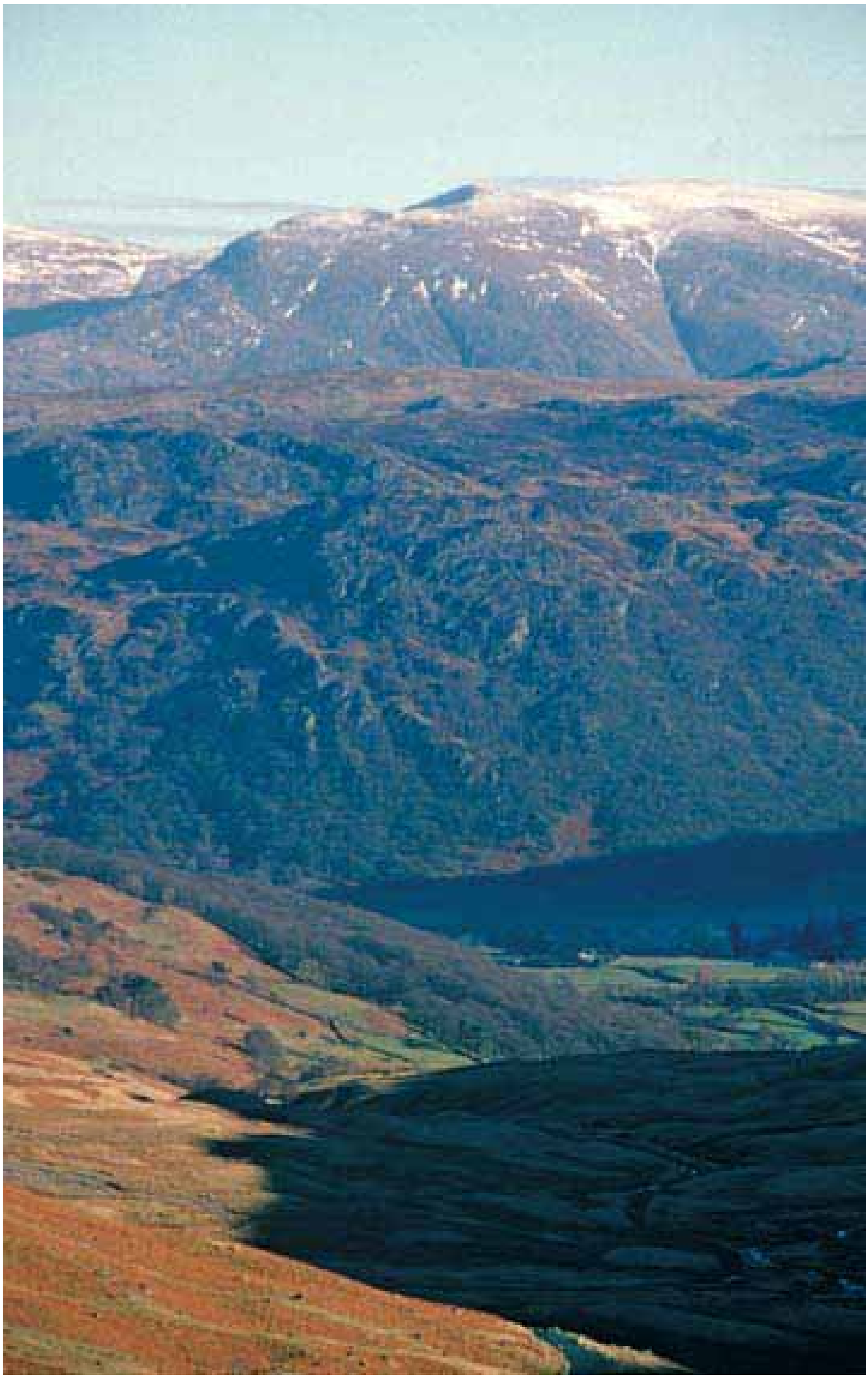
There is little information on the condition of geology and geomorphology outside protected sites. The Association of UK RIGS Groups has established a national geoconservation database, available for use by all local geoconservation groups, which has a section on the current condition of, and possible threats to, RIGS. At present only a few are using this database to record information, and there is no national funding scheme for active management of RIGS in poor condition.

Re-exposed workings in the Harford Sand at Sand Mine Quarry, Cleeve Hill.

Gloucestershire Geoconservation Trust

5.2 Landscape

Paul Glendell/English Nature 23,071



Borrowdale with snow capped Helvellyn behind, Lake District.

Landscapes are fundamental to the character of England. They are valued for their cultural and historic associations and their natural characteristics, and as the setting for people's lives, their work, relaxation and recreation. Recognition of the importance of landscapes as unique, dynamic settings for human activity has focused attention on the need to understand, conserve and enhance landscapes everywhere, both within and without protected areas.

England's finest landscapes are designated as Areas of Outstanding Natural Beauty (AONBs), National Parks and Heritage Coasts. AONBs and National Parks are selected for their 'natural beauty'. No two areas are the same, reflecting their geodiversity, so each designation is considered on its own merits, with the criteria given different weight and emphasis (Countryside Agency 2000). From 1970, outstanding stretches of undeveloped coastline have been defined as Heritage Coasts, and given strict protection from development. Thirty-two per cent of the English coastline, most of it within AONBs or National Parks, is now designated as Heritage Coast.

In 1995, the *Pan-European Biological and Landscape Diversity Strategy* (Council of Europe 1996) recognised that "Geological landscapes and sites of Europe, such as dune systems, creek systems, eskers, drumlins and bogs, are disappearing forever". This strategy set a common vision for protecting "geological and cultural features determining landscape identity", integrating biological, landscape diversity, social and economic sectors. This was taken further in the *European Landscape Convention* (Council of Europe 2000). The convention (signed by the UK in February 2006) calls on signatories to recognise and protect the wider landscape, both urban and rural, and to involve local communities in defining and assessing 'Landscape Quality Objectives', as well as in planning action to enhance, restore and create landscape features. This includes the radical reshaping of damaged or degraded landscapes.

In England, nationally designated landscapes are the best protected. This protection is now supplemented beyond these designated areas by measures to maintain and enhance the landscape. This wider approach is promoted in the Government's *Planning Policy Statement 7: Sustainable Development in Rural Areas* (ODPM 2004a) and is being achieved through a range of means including criteria-based policies, the Countryside Character Network and Landscape Character Assessment.

Landscape Character Assessment describes and assesses existing landscapes. It provides a useful tool for local authorities and others to inform landscape management, land use strategies and conservation policies. It also links to assessments of sensitivity and the capacity to ensure that change and development do not undermine distinctive key landscape characteristics or valued landscape features.

East Cliff near West Bay on the Dorset Coast.

Richard Cottle

Main steps in Landscape Character Assessment

Stage 1: Characterisation

These are the practical steps involved in initiating a study, identifying areas of distinctive character, classifying and mapping them and describing their character:

Step 1: Defining the scope. The purpose of the Landscape Character Assessments will critically influence the scale and level of detail, the resources required, those who should be involved, and the types of judgement needed to inform decisions. Scoping should include a familiarisation visit to learn more about the local character of the landscape.

Step 2: Desk study. This involves a review of relevant background reports, other data and mapped information on attributes such as geology, topography, drainage patterns, soils, vegetation, historical land use and settlement pattern. These sources are used to develop map overlays to identify areas of common character (usually draft landscape character types and/or areas).

Step 3: Field survey. Field data is collected to test and refine the draft landscape character types/areas, to inform written descriptions of their character, to identify aesthetic and perceptual qualities, and to identify the current condition of landscape elements.

Step 4: Classification and description. Field data are used to refine and finalise the landscape character types and/or areas, map their extent (based on all the information collected), and prepare clear descriptions of their character. These descriptions will often recognise 'forces for change', such as key development pressures and trends in land management.

Stage 2: Making judgements

Step 5: Deciding the approach to judgements. Judgement making varies according to the overall approach, the criteria to be used, the information needed to support the judgements and the role of stakeholders. Judgements about landscape value may require field survey information such as the condition of landscape features and the sensitivity of the landscape to change. Evidence may be needed about how artists, writers and others have perceived the area. Additional field work may be required to clarify areas of doubt or investigate new angles.

Step 6: Making judgements. The nature of the judgements and the resulting outputs will vary according to the purpose of the assessment and will have a variety of uses. For example, judgements using the landscape assessment process may be used in landscape strategies and guidelines, by attaching status to landscapes or by defining landscape capacity.

Landscape Character Assessment, based on Countryside Agency and Scottish Natural Heritage guidance produced in 2002, is now widely accepted as the principal tool for the description and assessment of landscapes across England and Scotland. It can be applied at a range of scales and across the quality spectrum, ranging from our finest landscapes to areas of damaged or degraded landscape. In England, there are 159 Joint Character Areas, which provide a spatial landscape framework within which more detailed Landscape Character Assessments can take place. Joint Character Areas combine Natural Areas (English Nature 1993), developed by English Nature, and Countryside Character Areas (Countryside Commission 1996), developed by the Countryside Agency. Each Joint Character Area is described in terms of its main physical, historical and cultural influences, its building and settlement patterns and its land cover with a summary of key characteristics. These descriptions together with a summary of the pressures for change and an assessment of how the negative impacts of change might be mitigated are published in eight regional 'Countryside Character' volumes (Countryside Commission & English Nature 1997–1999).

The Living Landscape Project (Griffiths and others 2004) developed a way of further dividing Joint Character Areas, using mapped (computer generated) national datasets. The project defined Landscape Description Units (LDUs) at 1:250,000 scale, based on physiography (encompassing geodiversity), ground type, land cover and settlement, producing full national coverage of 1,789 'level 1' LDUs. Since then 'level 2' LDUs, at 1:50,000 scale, have been defined for Oxfordshire and five West Midland counties. These were based on more detailed information on landform, structural geology and rock type, soils, farm type and crop cover, tree cover and settlement. This more detailed description requires expert assessment and field testing to refine the boundaries. It will be appropriate for local policy development, for mapping habitat potential and for local communities to identify their priorities and objectives. At a more detailed level, the approach can also be used to inform the management of individual farms and landholdings.

High Force, Upper Teesdale.

Mick Murphy/English Nature

Outside designated areas, Landscape Character Assessment can have real strength in ensuring that change and development do not undermine characteristic or valued landscape features. Some local authorities have used Landscape Character Assessment as the basis for Supplementary Planning Guidance or as the strategic context for the development and implementation of Local and Structure Plan policies relating to new development and land use change. This approach should be taken forward in the new Local Development Frameworks and Local Development Documents.

Burwardsley parish landscape

Burwardsley, near Chester, is the first parish in the country to use Landscape Character Assessment to understand what the landscape is like today and how it may change in the future. A 'Parish Statement' is being developed, researched, written and edited by local people, supported by the Parish Council, the Cheshire Landscape Trust and the University of Salford, funded by the Countryside Agency.

The Parish Statement describes the character and landscape setting of the parish and will draw out the way that these factors interact together and are perceived. So far the group has identified 12 'Landscape Areas' and written descriptions of each area and their key characteristics. The next stage is to work with local landowners and farmers to consider potential landscape enhancements. This will aid future development decisions, including potential adoption by the local planning authority as a Supplementary Planning Document.

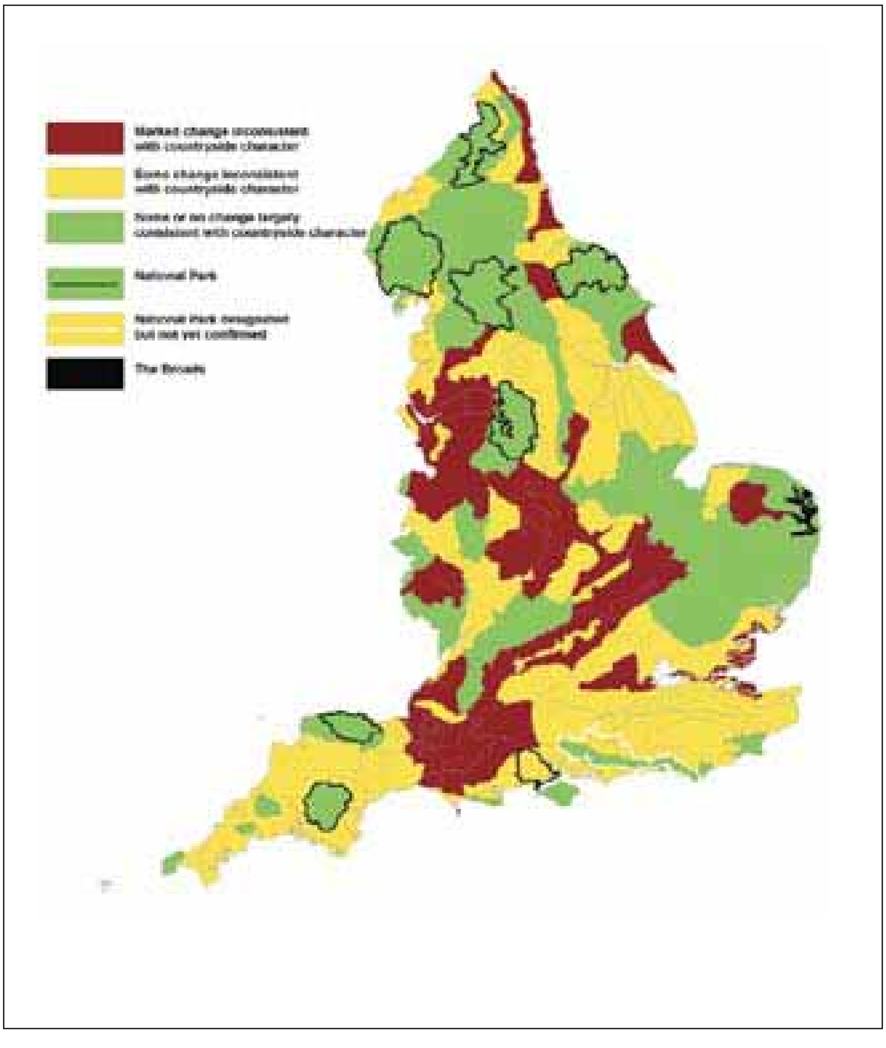
There is, potential to make more effective use of the Landscape Character Assessment framework. There is, however, still only partial coverage of England at the more detailed levels. There are also differences in the approach to Landscape Character Assessment between the agencies and across the country, particularly where assessments pre-dated the national guidance. As the range of approaches to landscape assessment matures and applications develop, it is likely that there will be parallel development of different assessment tools to suit different purposes.

There is a growing acceptance that greater consistency is required, striking a balance between nationally accepted best practice and the need to accommodate local variations to suit local needs and priorities. One challenge is to find ways of reading landscape assessments across administrative boundaries, so that they can inform resource planning and land management studies at sub-regional and regional scale. There also needs to be better stakeholder consultation at all stages. The Countryside Character Network, established by the Countryside Agency (website at: www.ccnetwork.org.uk/ [Accessed 5 May 2005]), draws together a range of partners and stakeholders involved in managing, conserving and enhancing the countryside, to exchange ideas and experience and work towards a suite of tools that meets everyone's needs. It manages a web-based database (on website at www.ccnetwork.org.uk/db/index.htm [Accessed 5 May 2005]) which holds current guidance and shows where landscape assessments that follow current advice are in place. This database is updated monthly as information on more landscape character assessments becomes available.

Monitoring landscape change

Joint Character Areas provide the reporting framework for 'Countryside Quality Counts' – the first national indicator of change in the countryside (Haines-Young and others 2004). This was developed in response to the Government's *Rural White Paper* commitment (DETR & MAFF 2000) to find out how the countryside as a whole is 'doing'. This project, led by the Countryside Agency, in partnership with English Nature, Defra and English Heritage measured changes in woodland, boundary features, agriculture, settlement and development, semi-natural habitats, historic features, rivers and coastal elements, over the period 1990–1998. These changes were assessed to determine whether they were significant and 'consistent' or 'inconsistent' with the then prevailing countryside character. This character was described in a set of Character Area Profiles, based on the descriptions in the eight regional volumes on Countryside Character. The analysis was based on expert and stakeholder judgements. The assessments are auditable and supported by quantified evidence (Countryside Quality Counts website at: www.cqc.org.uk [Accessed 28 February 2006]).

Countryside Quality Counts Headlines Indicator Map 1990 to 1998. Countryside Agency



Countryside Quality Counts found that, between 1990 and 1998, 42 per cent of our landscapes were either stable or showed change that was consistent with existing countryside character. For 26 per cent of our landscapes the change was marked and inconsistent with countryside character. In the remaining 32 per cent of our landscapes the change was inconsistent, but less significant in the overall impact on character.

The Countryside Quality Counts project deliberately avoids making value judgements regarding this change. For example, in areas of degraded landscape, change in character could be construed as beneficial. The purpose of this indicator is to inform people about trends in change and their impacts to assist in planning for, and managing, change in their local countryside.

Monitoring issues raised by the Countryside Quality Counts project

The Countryside Quality Counts project drew on many different data sets held by a range of agencies and organisations, and confirmed some major deficiencies:

- Inconsistencies in the application of Landscape Character Assessment.
- A need to update the Countryside Character Area Profiles (particularly to reflect the result of Historic Landscape Assessments), to provide a better framework for evaluation of change when the indicator is next run.
- A range of dates for the baseline data for a number of other data sets.
- Constraints in the application of some datasets at a detailed level due to inadequate sampling frequency or inappropriate scale of data collection.
- Inability to discriminate between certain features due to mismatch between the objectives of this analysis and those of the original data collection exercises.
- Confidentiality restrictions in accessing detailed data on agricultural land use information held by statutory agencies.
- A ‘major deficiency’ in “data on the location and extent of river and coastal engineering and its modification in the context of developing more sustainable management strategies”.
- Lack of conceptual approaches, detailed monitoring frameworks or adequate data for measuring some elements of landscape character such as tranquillity, accessibility and stakeholder attitudes.

The method is being developed, more and improved datasets are being identified, and the indicator will be run again in 2006, for the period 1999 to 2003.

National Parks have developed a variety of monitoring methods, the most recent of which have used Landscape Character Assessment to develop a suite of State of the Park Indicators, for example in the Peak District National Park (2004). Many AONB partnerships also have their own Landscape Character Assessments, which are used in the preparation of their new Management Plans (Countryside Agency 2001). During 2005, Countryside Quality Counts data are being re-packaged for National Parks and AONBs, to provide another tool to help monitor landscape change in our most highly valued landscapes.

5.3 Soils

Soils link the underlying geology with surface habitats, species and land uses. At any given location, soils reflect the interaction of five soil-forming factors; raw material, climate, topography, vegetation and fauna. Soil is a living entity and soil biodiversity is known to be greater than above-ground biodiversity, but is still poorly understood. Although English soils are young in a world context, they represent 10,000 years of ecological processes, and so are irreplaceable.

Holme Fen NNR, Cambridgeshire. The associated rich fen peat soils influence the surrounding agriculture and landscape of the region and the character of Holme Fen's biodiversity.

Mick Murphy/English Nature

Soil biodiversity

Over 100 species of soil fungi and invertebrates (such as solitary wasps) are known to be rare or vulnerable. These are species which use soil as a growing medium or place to live. Their status is mainly affected by factors such as the availability of bare ground and/or their relationship with host species.

Much less, however, is known about those species that form the essential components of the soil ecosystem, many of which are micro species but form a significant biomass. The biodiversity of 'soil organisms', both macro and micro species, drives the essential soil-forming and cycling processes. What evidence there is, suggests that soil organisms may be generalists, rather than specialists. As such, they may be important principally for their functional role, and the way that this is affected by human activities, rather than for their rarity.

Monitoring soil biodiversity

Problems in assessing the soil fauna arise in part from issues of scale. There is a huge array of species, not all of which have been identified, and, as many are microscopic, they exist in huge numbers. Many current methods for monitoring soil biodiversity use indirect measures such as soil microbial biomass and soil respiration rates.

Mick Murphy/English Nature

The Yorkshire Wolds, typically a shallow, lime-rich soil.

The Soil Survey of England and Wales (now the Soil Survey and Land Research Centre) drew up the National Soil Map of England. This shows the extent and location of soils, but their quality and diversity has not yet been evaluated to enable us to identify and protect a national network of representative or special soils. A methodology to assess the nature conservation value of soil, based on rarity, diversity and representativeness, is being developed as part of the nature conservation agencies' research programme. It is based on the relationship between soils, geology, landforms, and habitat and species distribution. The agencies will also consider how this information can be used for monitoring soil function and quality in association with monitoring soil condition.

National soil datasets

The National Soil Map (NATMAP), held at the National Soil Resources Institute (NSRI), is based on detailed fieldwork, and displays 300 soil associations digitally mapped at 1:250,000 scale. NATMAP includes 1, 2 and 5 km^2 digital 'gridded-vector' maps and the new soilscape maps. It maps 27 soil units, describes their environmental and ecological characteristics, and includes details of the types of habitat that could most easily be developed on them.

The National Soil Map is supported by the LandIS relational database and the National Soil Inventory. The database holds information such as soil profile descriptions, soil and topsoil chemistry, representative values or properties and derived functional values for soil series. These cover pesticide leaching and run-off classes, water regime and moisture release, and hydrological information.

The Inventory provides detailed information on soil samples taken at each intersect of a 5 km grid that was initially sampled in 1980 and partially re-sampled on occasions in the 1990s. This statistically representative sample offers a valuable foundation for future monitoring of soil quality. The information available covers erosion, land use, lithological information and soil profiles. It also includes a flood risk indicator.

Exmoor National Park is dominated by a mix of acid, loamy uplands soils that can be vulnerable to erosion.

Peter Wakely/English Nature 12,623

Peter Wakely/English Nature 14,152

SSSIs include significant and unusual soils such as this soil derived from the sugar limestone on Widdy Bank Fell, North Pennines.

Sites of Special Scientific Interest (SSSIs) cover about seven per cent of the land area of England. There is evidence that this series of sites includes a good representation of the wide range of soil types (Gauld and others 2003). Habitats and ecosystems are fundamentally dependant on geology and soils. SSSIs, though not selected on this basis, will include both characteristic soils and significant and unusual soils, such as those derived from base rich serpentine on the Lizard, or the sugar limestone of Upper Teesdale. SSSI descriptions frequently refer to soil type and soil characteristics, reflecting the importance of this link with soils and their raw material. However, there is still much to learn about the relationship between the species found on SSSIs and soils, as many tolerate a wide range of soil conditions.

In SSSIs, soils are protected from a range of potentially damaging activities and so the sites include relatively undisturbed or 'least modified' soils. Some of these soils have a long monitoring history, which is valuable for environmental research. English Nature is currently considering how the SSSI series can be of use in soil research. Such research would cover relatively large areas, encompassing a suite of soil types, to demonstrate the links between geology, soils and habitats and to investigate the management requirements for all three. In order to minimise inadvertent damage to soils on SSSIs and National Nature Reserves, English Nature has produced a position paper on the protection and management of soils within protected sites. It will also be issuing guidance on the use of soils in the restoration of wildlife habitats.

Peter Wakely/English Nature 14,179

Moor House-Upper Teesdale NNR has a long history of soil research. It is currently being used for PhD research on changes in moorland soil in response to management practices, such as burning.

Outside the SSSI series, 80 per cent of England's soils are managed by farmers and foresters. Their management has, in the past, been primarily directed to maximising production, with less consideration given to long-term environmental sustainability. The role of soil in supporting wildlife and providing a range of environmental benefits is now more widely recognised. Environmental benefits include buffering and treating environmental pollution, regulating water flow and quality, nutrient recycling and carbon sequestration. Hence effort needs to be directed at the restoration of soils (and land) in poor condition, and this is increasingly recognised as being critical to sustainable development. Defra's *First Soil Action Plan for England* (2004a) seeks "to ensure that England's soils will be protected and managed to optimise the various functions that soils perform for society, in keeping with the principles of sustainable development and on the basis of sound evidence". This requires improvements in legislation as well as in the regulatory and political framework.

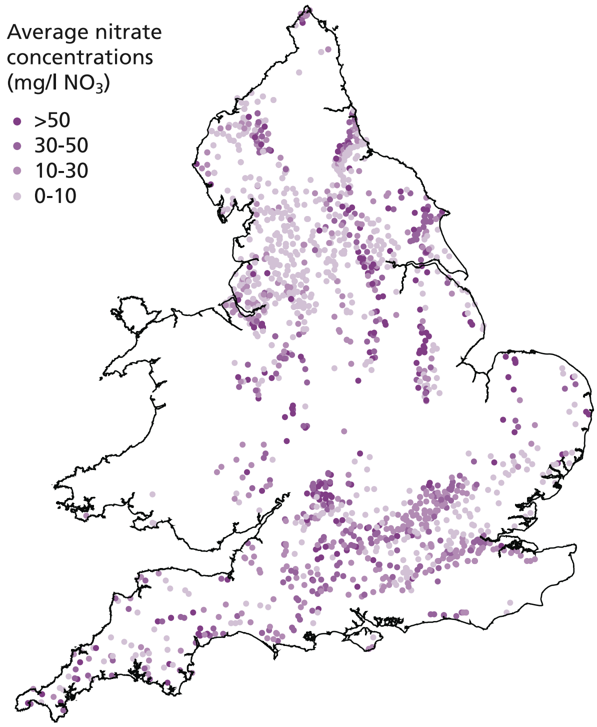
Hampshire soils initiative

Currently, local planning decisions are made on the basis of protecting the best and most versatile soils, defined by their agricultural use. In Hampshire, the county council has recognised that soils perform a range of other essential functions, which underpin Hampshire's environment, society and economy. They are also extremely vulnerable to various modern-day pressures which can destroy them in a matter of days.

Hampshire County Council's Soil Initiative is an example of best practice which should be applied more widely. Hampshire County Council

The council is establishing a county-wide initiative to address the issues facing Hampshire's soils to ensure their long-term sustainable management of this resource. This includes a more holistic approach to addressing soil issues in land use planning, highways management, biodiversity, landscape, minerals, waste management, water, climate change, archaeology and agriculture.

Nitrate concentrations in groundwater, 2000 to 2003



Source: Environment Agency

Monitoring soils

There is no comprehensive framework for monitoring soils in the UK. The Environment Agency's report on *The State of Soils in England and Wales* (2004) identifies vital gaps in our knowledge of soils. Some elements of soil condition are monitored through the National Soil Inventory, which collects and collates systematic data on soil. The British Geological Survey's Geochemical Baseline Survey of the Environment (G-BASE) holds information on stream sediment and water geochemistry. Other elements are monitored in various environmental schemes. Information on soil biota is included in *Countryside Survey 2000* (Haines-Young and others 2000). Broad indicators for net loss of green-field soils to development and for organic matter content in agricultural topsoils are included in the most recent set of sustainable development indicators (DETR 1999).

Some information on the condition of soils can also be obtained by monitoring the effects of their mismanagement on the wider environment. For example, inappropriate management of agricultural soils can lead to diffuse agricultural pollution which raises phosphate levels in rivers and nitrate concentrations in drinking water. Other issues, such as soil erosion, can be identified locally, for example from observations of increasing sediment loads in rivers and lakes. These effects are not yet monitored accurately at a national level but local and national research projects have modelled risk maps, for example for soil erosion and loss of phosphorus. In these maps, parameters such as field slope angle and length, soil type and geology are used to determine categories of vulnerability to erosion.

We do not yet have enough good quality information to define a scientifically robust set of national indicators that would cover the full range of soil functions and uses, or could be used to develop effective policies and programmes for soils. Defra's *First Soil Action Plan for England* includes a commitment to identify indicators which should be built into a national soil monitoring scheme in order to meet both national and European requirements. It is an on-going process with strong input from a range of stakeholders including English Nature and the Environment Agency. This is likely to be supported by a proposal from the European Commission to develop a Soil Framework Directive, which may establish the basis for an EU soil monitoring framework. It could also place obligations on member states to protect soil against loss of organic matter, contamination, erosion, salinisation, flood, sealing, compaction and loss of biodiversity. Defra will also work towards a soil health indicator based on organic matter content as part of the Sustainable Food and Farming Strategy (Defra 2002a).

6 Threats to geodiversity

There are many pressures, both man-made and natural, that can have a direct impact on geodiversity. Some of these threats, such as aerial pollution, have wide-ranging effects. Others, such as neglect, are specific to particular elements of geodiversity. Many of these threats also have an environmental, economic or social impact. Unsustainable action threatens both our geodiversity and the ability of our environment to function. For example, anything which disrupts natural processes may threaten geology and geomorphology (whether process or landform) and have a direct impact on landscape and soil. Geology is also fundamentally a field-based activity that requires physical access to rocks. Any action or development which impedes access to a geological exposure may therefore be considered as a threat.

This section reviews the threats to geodiversity and provides examples of actions underway to address them.

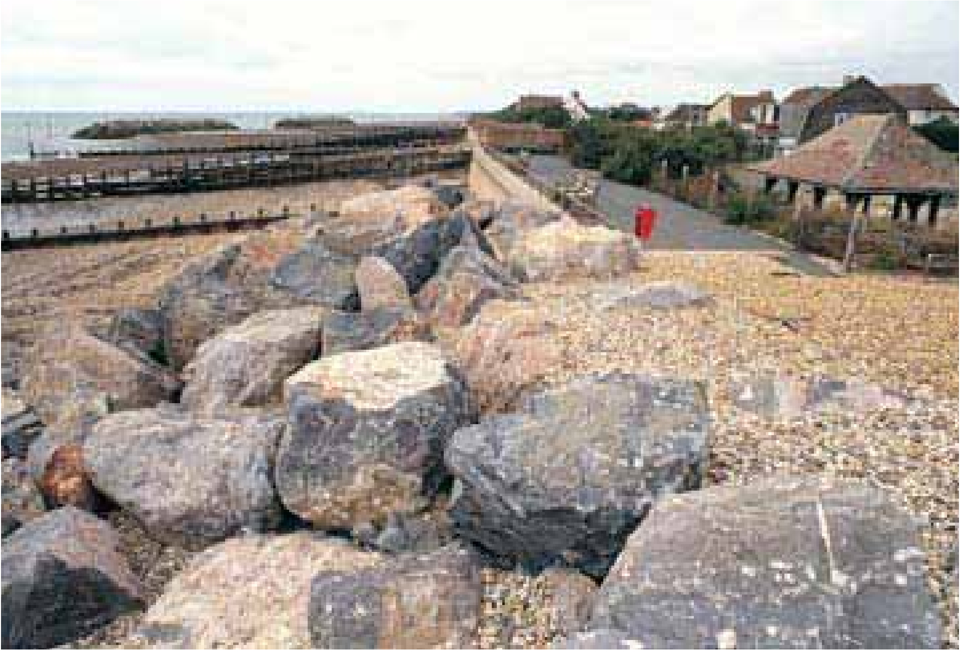
6.1 Planning

Coastal protection and engineering

Our eroding coastline is one of our most important assets for geological study, providing unequalled exposure and a vital window onto our geological past. However, cliff recession and coastal landslips present significant threats to land use and development. The combined effects of individual cliff failures can have significant cumulative effects: for example the Holderness coast has retreated by around 2 km over the last 1,000 years, with the loss of at least 26 villages listed in the Domesday survey of 1086.

Coastal development often leads to coastal protection which is a major threat to exposed and naturally eroding cliffs. Porthleven, Cornwall.

Mick Murphy/English Nature



Peter Wakely/English Nature 14,996

Coastal defence works pose the greatest threat to the geodiversity of our coastline. Bognor, West Sussex.

Until recently, the standard response to coastal erosion and flooding was to install coastal protection and engineering works. Over the last 100 years some 860 km of coast protection works have been constructed to prevent the losses associated with cliff recession or to protect low-lying areas prone to coastal erosion (MAFF 1994).

Development, such as artificial sea defences, can cover up geological exposures and prevent active cliff erosion, which normally maintains fresh geological exposures and releases sediment into the sea. Reducing the sediment supply, or interrupting sediment transport along the coast – for example, by moving shingle for artificial beach replenishment – can starve other areas of sediment. Without a natural sediment supply, beaches, saltmarshes and sand dunes cannot adjust to changing sea levels or current circulation patterns and lose their ability to act as natural sea defences. This can have serious social and economic consequences arising from the increased risks to property. Also as sea level rises, coastal erosion and flooding will increase and the need for carefully planned coastal management will be more important.

Coastal erosion threatens this gas terminal on the Holderness coast.

Peter Wakely/English Nature 15,721

Paul Glendell/English Nature 25,934

We now have a legacy of development sites in places vulnerable to coastal erosion and flooding.

We now have an inheritance of communities and developments that are vulnerable to coastal erosion and flooding. This creates continuing pressure to provide coastal defences and to maintain and renew existing coast protection works, especially in the face of the impacts of climate change.

In 2002, the European Commission confirmed the pressures and problems facing the coast, including limited understanding of coastal processes and dynamics, and made a *Recommendation concerning the implementation of Integrated Coastal Zone Management* (European Parliament and Council of the European Union 2002). Defra published practical guidance on effective coastal cliff management, taking account of cliff recession characteristics and trends as well as the risks to coastal communities (Lee 2002; Lee & Clark 2002). The UK Government endorsed the use of an 'ecosystem based approach' for the maritime environment (Defra 2002b) which recognises the importance of geomorphological processes to sustaining a naturally functioning coast. Such an approach would reduce threats to our coastal geology and promote action to restore damaged systems and sites. This is already occurring through 'managed realignment' (Pethick 1994) at a number of sites where, by breaching defences or allowing natural erosion, the sea defence line will be set back to allow the resumption of natural inter-tidal processes.

Managed realignment on the Humber Estuary

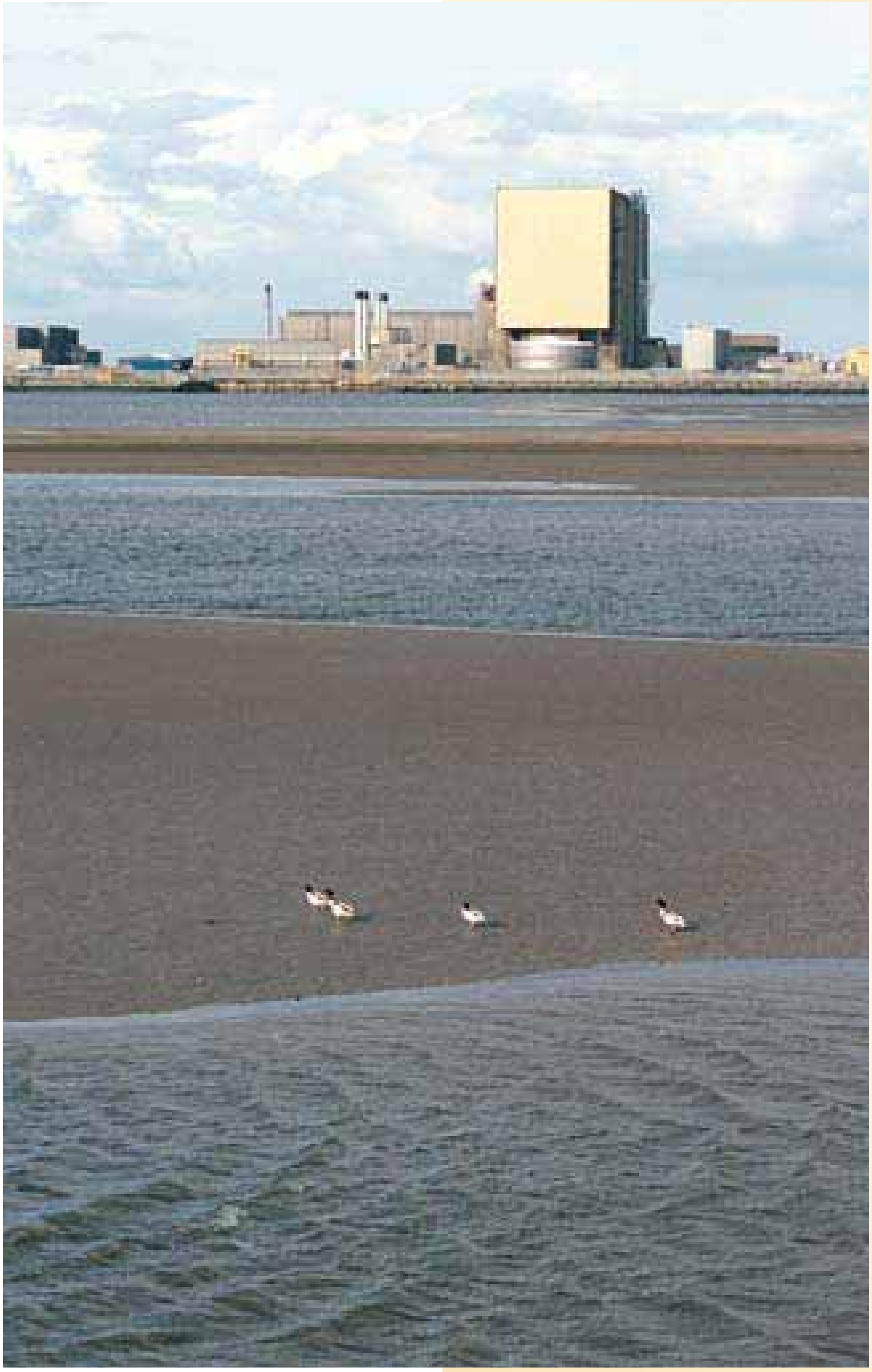
The Humber is one of England's biggest tidal estuaries with two large ports, Hull and Grimsby, and around 300,000 people living in its floodplain. Nearly 90,000 ha of land is at or below the level of the highest tides and, with rising sea levels, it is estimated that 460 ha of mudflat and saltmarsh will be lost over the next 50 years.

The Environment Agency has identified a range of sites where sea defences will be breached to allow inward migration of habitats. One such site is Alkborough Flats, recently purchased by the Environment Agency and English Nature, where breaching of the sea wall will provide 440 ha of wildlife habitat.

This managed realignment at Paull Holme compensates for a series of developments on the Humber Estuary. Environment Agency & Image Aviation

The Government's national 'stock take' report (Atkins 2004) identifies the legislation, institutions and stakeholders involved in Coastal Zone Management as a first step towards a national strategy for integrated coastal zone management. Further support for this approach comes from the publication in 2004 of the Foresight report *Future Flooding* and the Eurosion Study *Living with Coastal Erosion in Europe* (Doody and others 2004) which reviews lessons learned from projects across Europe. Both highlight the importance of planning for sustainable coastal management, over long time periods, to adapt to climate change.

Shoreline Management Plans should offer opportunities to consider a range of options to manage erosion risk and deliver sustainable coastal management.



Peter Wakely/English Nature 17,486

Shoreline Management Plans

Shoreline Management Plans (SMPs) were first prepared for England in the 1990s. In 2001 a review of these plans identified many issues to be addressed, including environmental enhancement opportunities to help deliver sustainable coastal defences. Second generation SMPs (Defra 2001), being prepared for three trial areas in Norfolk, Kent, and Sussex, look set to propose a more sustainable approach to coastal management over the next 100 years.

Defra has issued new guidance to help coastal groups review SMPs by utilising resources such as:

- the 'Futurecoast' CD-ROM;
- recent research on the implications of climate change;
- research into biodiversity and geological interests (Dalton and others 2004); and
- the 'Living with the Sea' project, which examined the impacts of sea level rise on internationally important SSSIs.

SMPs are non-statutory documents, so they will require integration with erosion risk planning in Local Development Frameworks, Regional Spatial Strategies and other coastal strategies.

English Nature's maritime strategy, *Our coasts and seas – making space for people, industry and wildlife* (English Nature 2005) confirms the importance of effective marine spatial planning, including adopting the Ecosystem Approach (see Text Box page 49) and moving from coastal defence to coastal management. A central theme of this strategy is adaptation to change in the face of sea level rise, increasing storminess and limited resources to maintain the current coastal landscape. Some hard choices will be needed, on land and at sea.

Coastal development restricting natural erosion of chalk cliffs which have now greened over.

Peter Wakely/English Nature 10,058

Development

Development, such as new road cuttings, can create new rock exposures, both temporary and permanent, for research, education or recreation. These can mitigate the impacts of past damage to geological processes, landscape or soils. However, development undertaken without consideration for existing geological features can rapidly and needlessly damage or destroy them.

Development of buildings and infrastructure, including new or widened road and rail corridors, can lead to land take and loss of finite geological resources, disruption of natural processes, and irreparable damage to landforms, landscapes and soils. About 11 per cent of England is covered in residential and industrial development and infrastructure (Defra 2003). By 2016, another 1.3 per cent of England is predicted to disappear under development, much of it to meet the demand for an extra 3.6 million households (ODPM 2004b). The infrastructure required to support development often causes further problems.

Secondary impacts of development

- Rock faces in quarries and cliffs often suffer from attempts to extend the gardens and holdings of nearby developments, such as new fencing and tree planting too close to the face.

- Development along rivers can lead to water flow regulation, or water transfer, to maintain adequate supplies of drinking water and to support effluent treatment. Installation of weirs, bank stabilisation works, and dredging to maintain water depths for navigation can all disrupt natural fluvial processes.

- Impermeable surfaces, such as concrete and tarmac, reduce water infiltration to the soil. This can reduce aquifer recharge, and the excess surface flows can cause flooding in urban areas.

- 'Soil sealing' occurs when soil removed or covered by new development is permanently lost.

Development that is not sensitive to local character causes visual intrusion and degradation of the quality of the landscape. This can include insensitive location of housing, industrial development, installation of wind farms and mobile phone masts. New tree and woodland planting designed to mitigate such impacts is often insensitive to existing tree and woodland patterns. The use of artificial mounds and bunding to dispose of surplus soil, and to act as screens or sound barriers, is often insensitive to local landscape texture and destroys or degrades landscape character (Gray 2004). In some cases, this destroys the wider landscape context for remaining geological or geomorphological sites.

Development laying waste to geological sites, landscape and soil.

Peter Wakely/English Nature 17,329

Peter Wakely/English Nature 13,903

Soil can be restored, if stripped, handled, stored and replaced carefully.

Natalie Bennett/English Nature

Subject to conditions, planning consent has been granted for development in Purfleet Chalk Pits SSSI. The walls of these quarries expose nationally important deposits of fossil-rich sands and gravels, laid down by an early tributary of the River Thames.

Aftercare and restoration of development sites are crucial to mitigating impacts on all elements of geodiversity. Storage, handling and replacement of soils must be done in a sensitive manner to restore some soil function. Planners and resource managers must be alerted to the potential damage to geodiversity that land use change can cause and to how this damage can be averted. The best way to achieve this is through effective use of the planning system.

Helen Stace

At Easter Park Farm, consent for building on the quarry floor was conditional on work to re-expose and maintain access to the quarry face.

Geodiversity needs to be considered at every stage of planning, including the potential impact of development, how negative impacts can be prevented or mitigated and where, through better planning, there are opportunities to benefit geodiversity. Landscape character assessment, incorporating capacity and sensitivity analysis, can help to evaluate the potential damage of any major land use change. Planning conditions and obligations can be used to increase the number of permanent rock exposures, re-establish natural systems, restore the ecological function of soil and fund monitoring and maintenance work.

Protecting geology outside designated sites

Dudley Metropolitan Borough has an exceptionally important geological heritage, including many existing exposures in quarries, mines and cuttings. The council wants to maximise the benefits of the borough's geology, and developers have a key, positive role to play in conserving and enhancing this resource, especially where their proposals could create fresh exposures of rock.

Under Policy NC7 in the post inquiry Unitary Development Plan, the council requires developers to follow the draft Supplementary Planning Guidance for 'Nature Conservation – Geology'. This sets out the procedures for developers to follow, including a flow chart for assessing the geological significance of potential development sites. Options include recording and sampling prior to development and the creation of new exposures. This is usually funded by the developers, under the terms of conditions, and/or planning obligations, attached to planning consent.

Peter Wakely/English Nature 20,318

Natural river features being restored on the River Cole, Oxfordshire.

River engineering

Natural rivers flow at different rates over different terrain, changing their courses through time and developing a range of river features such as riffles, sand bars and meanders. Rivers can maintain important geological exposures in river banks and cliffs, both along the channel and across their floodplain. Eighty-five per cent of lowland rivers in England have been physically altered, and disconnected from their flood plain (Defra 2002c). Rivers have been canalised for flood control, for drainage, to prevent erosion, to improve navigation, to protect roads and railways following river valleys, to fix the channel through towns and to make them 'look tidy' (Brookes and others 1983).

Natural river features being restored on the River Itchen, Hampshire.

Peter Wakely/English Nature 17,925

River engineering and gravel extraction, on all scales, can damage or remove geological exposures, disrupt the natural river processes, change the landscape character and drive changes in ecological character and functionality. Changing these natural fluvial processes can damage river and flood plain features both directly and indirectly. A number of changes can occur where rivers are artificially confined:

- increased flow rates can increase erosion;
- flood flows from urban areas can double the size of downstream channels, (Gregory 1976); and
- dams can reduce upstream and downstream flows leading to deposition of sediment, as on the Derbyshire Derwent (Petts 1997).

River engineering can reduce the quality of river landscapes, and can have impacts on soils in the catchment, such as limiting the input of new silt during flood events. Where river engineering affects the water table and changes soil drainage patterns, this can also impact on the quality and quantity of water going through or retained by soils. In addition to the environmental cost, these changes have an economic impact.

Alternatives to flood defences

Building ever higher flood defences is costly and, in many circumstances, unsustainable. It is time to start using alternative approaches, based on reducing and slowing run-off from the land and using the natural storage capacity of flood plains. Schemes working with natural processes to reduce flood risk, for example by restoring washlands, can benefit wildlife and improve water quality by reducing soil erosion.

The Government's new strategy *Making Space for Water* (Defra 2005b) promotes a more holistic approach to managing flood and coastal erosion risks in England. This will reduce the threat to people and their property and deliver significant environmental, social and economic benefits, consistent with the Government's sustainable development principles. The strategy includes commitments to:

- ensure adaptability to climate change is integral to all flood and coastal erosion management decisions;
- adopt a whole catchment and whole shoreline approach that is consistent with, and contributes to the implementation of, the Water Framework Directive; and
- make greater use of rural land use solutions such as the creation of wetlands and washlands, and managed realignment of coasts and rivers.

Catchment Flood Management Plans will be a strategic planning tool through which the Environment Agency will work with other key decision-makers to identify and agree policies for sustainable flood risk management.

Paul Glendell/English Nature 25,059

New houses should not be built in flood plains, Upton upon Severn.

River flood plains provide natural protection by accommodating flood water, Somerset Levels.

Paul Glendell/English Nature 25,142

Large quarries can provide extensive three-dimensional rock exposures.

Clive Nicholas/David Roche GeoConsulting

Mineral and aggregate extraction

Rock faces in quarries and pits are crucial to the understanding of geology, especially in low-lying areas with few natural outcrops – 95 out of 1,241 geological SSSIs are active quarries and pits and 424 are disused quarries and pits. They provide a major resource of valuable new exposures for geological research and education. Large quarries and pits provide extensive exposures, whilst the numerous smaller sites provide important windows onto a more diverse sample of the geological succession. Worked-out extraction sites can also have high wildlife interest, either through natural re-colonisation or deliberate restoration.

Minerals and aggregates are a major economic resource. In aggregates alone, there are many major companies and over a hundred smaller operators. The major operators manage a significant number of SSSIs in England. For example, between them, Hanson Plc, Tarmac, Lafarge, RMC and Aggregate Industries manage 142 SSSIs, including a National Nature Reserve. Minerals and aggregates can only be extracted where they occur, so there needs to be a careful balance between the loss of surface geology and features and the value of the resource to be extracted. English Nature works closely with the minerals industry to minimise damage from poorly sited extraction and ensure effective restoration and after-use.

Mineral industry initiatives

The mineral industry leads the field in recognising its corporate social responsibilities. It has taken up the challenge to implement sustainable development and play an active role in the conservation of geodiversity. Minerals operators are keen to promote their image by working with local geoconservation groups and engaging in local projects and initiatives.

The Minerals and Nature Conservation Forum

This forum meets regularly to discuss national and local issues. It works to develop measures of the industry's contribution to biodiversity and geodiversity, and to ensure the industry is delivering favourable condition on its SSSIs. The forum runs joint training events, has an informative website and issues good practice guides such as: *Biodiversity and minerals – extracting the benefits for wildlife* (Knightsbridge and others 1999) and *Breaking new ground* (Mining, Minerals and Sustainable Development Project 2002).

Company initiatives

- In 2001, Lafarge published: *From working quarry to wildlife haven*, detailing its contribution to conservation across the country.
- English Nature has recently signed a Memorandum of Understanding with the Quarry Products Association (QPA), the Silica and Moulding Sand Association (SAMSA) and the British Marine Aggregate Producers' Association (BMAPA) aimed at achieving environmentally sustainable development in the minerals industry.
- Hanson Quarry Products Europe has a Memorandum of Understanding with English Nature, including a commitment to managing all 42 SSSIs under their control in England (Denley and Prosser 2001).
- A number of aggregate companies now report annually on the condition of SSSIs in their control.
- In 2003 English Nature, the QPA and SAMSA published *Geodiversity and the minerals industry – conserving our geological heritage* (English Nature, Quarry Products Association and Silica and Moulding Sands Association 2003), a guide to conserving geological features during mineral extraction.
- Mineral operators, such as Tarmac, are developing Geodiversity Action Plans. These will provide realistic company-wide strategies for the sustainable use of geological resources for amenity, conservation, education and research into their business objectives.
- The Quarry Products Association have developed a four-point plan for quarrying in National Parks and its annual restoration awards include a category for biodiversity and geodiversity.

Good practice guides published in partnership with the minerals industry.

Hanson Aggregates

Launch of the new interpretation panel and viewing platform at Clee Hill Quarry, funded by the Aggregates Levy Sustainability Fund.

Aggregates Levy Sustainability Fund

The Aggregates Levy is intended to decrease primary extraction and to increase recycling and the use of secondary aggregates. The levy stands at £1.60 per tonne for the primary extraction of sand, gravel, marine aggregates and crushed rock. Coal, clay and building stone are not taxed. Ten per cent of the revenue raised is set aside for use as the Aggregates Levy Sustainability Fund (ALSF) to deliver environmental benefits to offset the impacts of aggregate extraction.

During its first three years, English Nature's ALSF Grants Scheme supported over 190 projects and distributed a total of £10.8 million. English Nature and the Countryside Agency have formed a joint ALSF Partnership Scheme for 2005/06. This will tackle the problems caused by aggregates extraction that affect landscapes, biodiversity, geodiversity and communities in England, and improve access and recreation in affected areas. It has an allocation of about £5.7m for 2005/06 and £4m for 2006/07, plus £1m each year for marine projects.

In some cases, mineral and aggregate extraction can threaten to exhaust limited resources. It can also have impacts on other elements of geodiversity, in particular landscape, soils and hydrological processes. Many quarries and pits – as well as activities such as strip mining and peat winning – remove surface soils and sub-soils. These soils can be restored if they are stripped, handled and stored carefully, with good aftercare of restored areas. Where materials are washed during processing, silt can cause local pollution of water courses and some mining and quarrying activities can release toxic leachates. Pumping out water to allow mineral extraction can dry out surface soils and habitats and affect the underground hydrology of the surrounding area. In some cases, the impact of quarrying on geodiversity is complex and difficult to assess, involving more remote effects – as in the case of Slade Brook (see Text Box page 97). To avoid these problems, geodiversity considerations and objectives must be built into plans for the working and restoration of such sites.

Aggregate extraction for roadstone.

Peter Wakely/English Nature 19,319

Roger Meade/English Nature

Tufa dams on Slade Brook, Forest of Dean.

Slade Brook tufa dams

Slade Brook, on the edge of the Forest of Dean, is fed by several springs emerging from the local Carboniferous limestones. This spring water is saturated in calcium carbonate, which comes out of solution and is deposited as tufa. The deposits form dams over a 700 metre stretch of Slade Brook.

Because the nearby limestone quarry is hydrologically linked to Slade Brook, plans to extend it may have a direct impact on tufa formation. Following analysis and survey to gain a wider understanding of local hydrology, quarry expansion and restoration will be carried out in carefully managed stages. This should ensure that the water linking the quarry and the brook remains saturated in calcium carbonate to maintain tufa formation.

Around 10 per cent of England's aggregates come from the sea bed. In 2001, around 23 million tonnes of sand and gravel were dredged from licensed areas around the coast. In the south east, marine aggregates represent one-third of the total supply. The use of marine aggregates is driven primarily by the housing and construction market. However, the demand for beach re-nourishment material is an increasingly important market, with around 22 per cent of marine aggregate being used for fill and beach feeding. The move towards softer engineering in our coastal zone means this will continue to rise.

Beach recharge to protect a nuclear power station.

Peter Wakely/English Nature 20,907

Use of marine aggregates has a range of unseen, but none-the-less damaging, impacts including disruption of coastal processes and interruption or removal of the sediment supply that feeds the coastline. Sediment removal leads to beach starvation and reduced beach levels, followed by erosion of adjacent dunes and cliffs. Sand-winning from coastal locations, such as the mouth of the Hayle estuary (Cornwall), can have serious implications for beach levels and local economies.


Peter Wakely/English Nature 17,494

Sand extraction from the beach at Seal Sands, Teesmouth.

Quarry restoration and landfill

Once extraction ceases, disused quarries and pits, and their associated geodiversity, are faced with new pressures and threats, including quarry backfill or landfill, tipping, face instability and flooding. Careful restoration of used sites may have significant benefits for wildlife, for example restoring and recreating habitats and attracting new species, or for recreation, but can result in loss of geological exposures.

Buildings in disused quarries are often too close to the rock face, limiting access to geological exposures. Health and safety legislation and concerns about rock face stability may lead to demands for rock bolting, gabions or mesh which obscure the exposures. Where such stabilisation measures prevent active erosion, vegetation and scrub colonising the rock face can obscure the geological exposure and its context. However, properly designed development can make adequate allowance for maintaining exposures, including excavation of alternative sections.

Water pumped out of this pit is being used to restore the water table on a nearby heathland.


Stephen Parkhouse/David Roche GeoConsulting

Many sites were lost due to old planning consents for landfill that did not specify retention of conservation faces. With careful planning, a rock exposure can be retained within the landfill design, though often it can suffer from subsequent slumping, neglect and fly tipping. Some exposures are flooded or affected by toxic leachates or landfill gas, making access difficult, dangerous or unpleasant. However, with increasing experience, improved arrangements for working and rehabilitating the sites make it easier to retain and restore geological exposures.

Using sites for landfill can also disrupt local hydrological processes, potentially pollute groundwater supplies and contaminate surrounding land with toxic leachates. These problems have declined as the technical design of landfill has improved. Land raising can infill and obscure geomorphological features, such as old river channels or relict glacial features. The areas of raised ground created often fail to reflect the original landform, creating areas that lack landscape texture and interest and are inconsistent with local landscape character (Gray 2002).

Webster's Claypit

Webster's Claypit, in Coventry, once exposed sandstones and mudstones deposited on the floodplain of a river that flowed across the region approximately 300 million years ago.

The claypit was notified as an SSSI in the mid 1980s, after planning permission had already been granted to infill the site. Despite strong representation to the city council, proposing a compromise scheme that retained the geological exposure within the designed post-landfill green space, landfill was continued and completed.

Webster's Claypit demonstrates the vulnerability of geological sites to landfill, the need to gain early planning agreement on restoration and the importance of raising the profile of geology so that local communities value and support geological restoration.

Colin Prosser/English Nature

Webster's Claypit near Coventry – before landfill.

Webster's Claypit near Coventry – after landfill.
Colin Prosser/English Nature

The EU Landfill Directive and related legislation is changing the way we deal with waste, and making landfill a last resort. This is supported by progressive increases in landfill tax and drives to reduce waste and re-use or recycle. It is likely, however, that the legacy of landfill sites will become an issue in the future as liners degrade with time, potentially releasing pollutants.

Stephen Parkhouse/David Roche GeoConsulting

Fresh working faces reveal structures in the soft sediment.

6.2 Land management

Neglect and lack of management

The fact that geological sites need management is often forgotten. Rocks, fossils and minerals, exposed in artificial situations such as cuttings, or in natural outcrops, require active management to maintain the exposures and physical access to them. Approximately half of all geological SSSIs currently need vegetation or scree clearance, followed by on-going management to maintain exposures in favourable condition.

Natural weathering and erosion degrade exposures. Some soft-sediment sites weather quickly, destroying fresh surfaces. The collapsing sediment accumulates at the bottom of the face, obscuring parts of the section or, in extreme cases, the entire section (English Nature 2004b, Shelton 2004). Vegetation, such as scrub, bramble and ivy colonising the rock face, can damage the geological interest of soft-sediment sites, obscure specific geological features and limit views of the relationship between different features of the site.

Neglect can also be a problem for important landscape features such as dry-stone walls and vernacular buildings. Many of these features are no longer needed for modern farming, so there is little incentive to keep them in good repair. This is especially true where local materials are expensive or difficult to obtain and building styles require specialised skills or expensive repairs.

These soft sediments soon degrade when working ceases.

Stephen Parkhouse/David Roche GeoConsulting

Agriculture and forestry

Poor agricultural and forestry practice can cause direct and indirect threats to geodiversity. Geological sites, and surface and sub-surface geomorphological and geological features, can be damaged by deep ploughing. The disposal of ditch dredgings and crop washing waste can also obscure surface geomorphological features, such as abandoned meanders, which are often important to the local texture and quality of the landscape.

Past tree planting schemes often overlooked the impacts on geodiversity. Trees have been planted directly against rock exposures and over geomorphological sites, where tree roots can also penetrate and destroy sub-surface buried features. Plantations were established without consideration for landscape, both in terms of location and shape of plantings and in terms of the tree species used. Forestry can lead to changes in soil properties. For example, trees planted on peatlands or moorland can lead to drainage and podzolisation – leaching out nutrients from the surface layers of the soil. Soil can also be damaged by heavy machinery and by the creation of access tracks used during planting and harvesting.

Life after conifers

Two projects in northern England have been targeted at restoring natural landscapes, landforms, soils and vegetation that had been degraded by commercial conifer plantations. These are at Kielder Forest, the largest man-made forest in Europe, and the Lakes Forest District, which includes the ring of white limestone fringing Morecambe Bay. Some of the most impressive European examples of blanket peat, species-rich limestone pasture and spectacular limestone pavement – important for their geological and botanical value – survive in this area.

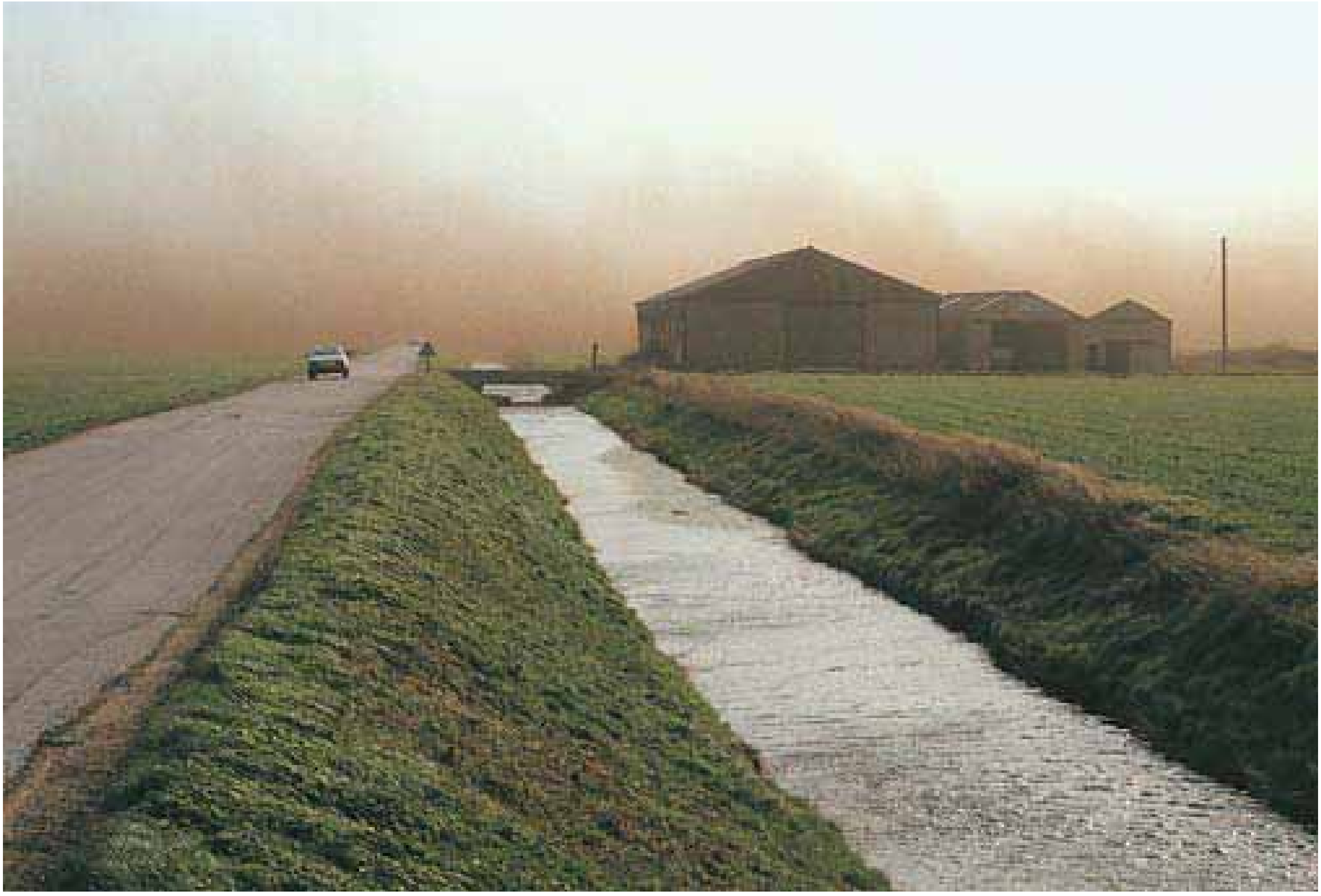
The conifers have significant impacts on landscape, soils and natural vegetation. The peatlands, grasslands and pavements depend on relatively low nutrient levels to prevent vigorous species taking over. Needle fall from mature plantations enriches the soil and the dark conifers shade out natural vegetation. Peatlands are degraded by forestry drains, and the trees themselves lower the water table (trees use about 80 per cent of the water lost from the peat).

English Nature and Forest Enterprise, with EU LIFE funding, are pioneering large-scale landscape and habitat restoration using specialist techniques. Since 2001, almost 500 hectares of plantation have been removed and further clearance was started in 2005. This work is expensive but the results are both impressive and rewarding.

Peat-forming bog mosses returned surprisingly rapidly at Kielder and, in cleared areas, the open moorland landscape so typical of the blanket bogs has been restored. Around Morecambe Bay, landscapes and landforms hidden for 25 years have re-emerged from their conifer cover, allowing the diverse mosaic of limestone habitats to thrive again.

Cambridge University

Large-scale habitat restoration at Whitbarrow, Cumbria. Re-exposure of limestone pavement from conifer plantation.



Peter Roworth/English Nature

Degraded peat blowing away in the wind.

Drainage of floodplains, peatlands and fens leads to drying out of soils; this results in the oxidisation of recent organic remains and the loss of the pollen record – a valuable tool that can be used to chart changes in vegetation and climate over several thousand years. Peat soils are extremely vulnerable to loss, particularly when they have been drained for peat working or agriculture. Once dried peat is exposed to the air it degrades, and carbon is oxidised and released as carbon dioxide. This degradation can be irreversible and seriously limits the ability of peat to act as a carbon sink. The peat also loses its structure and bulk, making it more vulnerable to erosion, and degraded peat colours water, increasing the costs of cleaning it for domestic consumption.

Inappropriate land management can damage agricultural soils, potentially limiting their agricultural capacity. Farmyard run-off and inappropriate disposal of manures and wastes can cause problems in water courses. Waste can also drain into caves causing pollution and staining of cave features. Soils left bare, or damaged by poor livestock management, can be susceptible to erosion and soil loss. Soil compaction by heavy machinery, or intensive stocking, also reduces water infiltration. This limits aquifer recharge and causes surface run-off problems. Erosion has visual impacts on landscape quality with adverse effects on recreation and tourism, whilst the sediment load creates a range of problems in receiving waters and also increases the costs of cleaning up after floods.

The impacts of soil loss

Erosion is a natural process of landscape evolution, but poor management of agricultural land increases soil loss. Erosion now moves some 2.2 million tonnes of arable topsoil annually and 17 per cent of soils show signs of erosion (Soil Survey 2000). In some areas this soil loss is no longer sustainable. This can have a serious impact on soil fertility and a range of off-site impacts which contribute to diffuse agricultural pollution.

Soil loss can increase the input of sediment to lakes, rivers and inshore coastal waters. Also, phosphates carried on soil particles, and nitrogen leached from soils, raise nutrient levels in receiving waters. Increased sediment loads in rivers can alter natural fluvial processes and affect rivers, lakes, fens, bogs, ditch systems, estuaries and coastal waters. This can infill lakes, smother plants and animals, cause excessive algal growth and reduce plant diversity and associated animal communities.

Many of our most cherished wildlife sites are under severe pressure, including rivers such as the Hampshire Avon, Herefordshire Wye, Test and Itchen, Slapton Ley (Devon), the Norfolk Broads and Cumbrian basin fens such as Moorthwaite Moss and Cliburn Moss. English Nature has identified around 100 designated wildlife sites where sediment problems need to be addressed as a matter of urgency. A further 100 sites are of additional concern (English Nature and ECUS 2003).

The Water Framework Directive, adopted in 2000, is the most important piece of legislation to affect water management across the European Union. It requires water bodies to achieve good ecological status by 2015. The Environment Agency's assessment of the pressures and impacts on water bodies, confirms the importance of diffuse pollution from agriculture (Environment Agency 2005). English Nature and the Environment Agency are drawing up criteria for river restoration, starting with river SSSIs. Measures will include tackling diffuse agricultural pollution and restoring natural fluvial processes, for example by reconnecting rivers to their floodplains and using wetlands as natural water storage reservoirs.

Soil erosion and run off along tractor ruts.
Paul Glendell/English Nature 25,249

Soil lost from agricultural land enters our rivers.

Paul Glendell/English Nature 25,074

English Nature has undertaken research on soil risk assessments and critical sediment yields for catchments in order to inform its work with organisations such as the Environment Agency and farming and wildlife advisory groups. English Nature, together with partners such as the Environment Agency, is also advising Defra on soil management in the development of the new agri-environment schemes. For example, following reform of the Common Agricultural Policy, the new Single Farm Payment requires farmers to demonstrate that they are keeping their land in Good Agricultural and Environmental Condition. Defra has issued a cross-compliance handbook (Defra & Rural Payments Agency 2005a) describing these measures, supplemented by specific guidance on soil management (Defra & RPA 2005b). In addition, improved soil management is covered by options in both the Entry Level and Higher Level of the new Environmental Stewardship Scheme (ESS). The need for improved soil management on farms is clear, but the ESS offers significant incentives, that will start to address this issue. Also, further research and action is required to minimise diffuse agricultural pollution due to inappropriate management of soils.

Other conservation interests

With the close dependence of habitats and species on geodiversity, there is little conflict between site management objectives for biological and geological interests – scrub clearance, for example, benefits both the geomorphology and the flora of a limestone pavement. However, there are some instances where conflicts can arise between the two (English Nature 2004c) or with other environmental interests (landscape, historical environment and access) and where compromise may have to be reached. A full understanding of all known interests is essential for integrated land management decisions to be undertaken.

Peter Wakely/English Nature 19,338

Lead spoil heaps support rare plants, Derbyshire.

Some contaminated sites, such as mine dumps, are renowned for those higher plants, mosses, liverworts and lichens that tolerate the high levels of metals that prevent other species from growing. Re-working the mine dumps to expose new geological specimens can assist these species by raising metal toxicity at the surface. This reduces competition from encroaching plants, however, enough of the original habitat must be retained to allow metal tolerant species to recolonise the re-worked areas. Also, mine dumps often have an industrial archaeological interest that should be taken into account when establishing the management of the site.


Paul Glendell/English Nature 23,051

Aerial pollution can be dispersed far from the source of emissions.

6.3 Contamination and pollution

Soil contaminants include metals, hydrocarbons and other organic pollutants, pathogens and substances that can acidify and/or enrich soils with nutrients. Sources of contamination can be local or diffuse. Local contamination can arise from active mining and industrial processes and accidental spills. The Environment Agency estimates that at least 300,000 hectares of land are affected by historical contamination by local industry, covering between 5,000 and 20,000 'problem sites' (information on land quality available at: www.environment-agency.gov.uk/subjects/landquality/[accessed 9 March 2005]).

Diffuse pollution arises from aerial deposition and from agricultural uses of land. It is also caused by run-off from roads, urban areas, industrial and construction sites. This causes widespread contamination of soils by sulphur and nitrogen. Whilst this adversely affects natural habitats on agricultural land, sulphur remains an important and declining trace element input whilst nitrogen reduces the need for inorganic fertilisers, heavy metals and persistent organic chemicals (Environment Agency 2004). Between 1995 and 1997, 71 per cent of lead, 54 per cent of arsenic, and 50 per cent of cadmium inputs to agricultural soils came from the air (MAFF and other 1998).

Paul Glendell/English Nature 22,607

Land spreading will be increasingly important for disposal of organic waste.

Diffuse pollution also comes from agricultural practices such as spreading of wastes, organic manures and sludges, as well as use of agricultural fertilisers and pesticides. Examples include addition of cadmium in phosphate fertilisers, and zinc and copper in manures derived from animal feed. Unless controlled, these could lead to agricultural products failing to meet statutory metal limits and an impairment of soil function. Eventually these practices could prejudice human health and render the ground unsafe for agricultural use or redevelopment without costly decontamination. Some methods for remediating contaminated sites may have undesirable effects, such as damaging or destroying soil structure or killing micro-organisms which survived the original contamination. Waste Management Licensing and Integrated Pollution Prevention and Control will be increasingly important in protecting the environment and human health against such contamination.

Contaminants that are not degraded by physico/chemical processes or soil micro-organisms can accumulate over long periods of time. These can be immobilised in the soil, or leached out to affect other areas. Slow release or erosion and redeposition can contaminate other areas, for example lead from old mines in the Yorkshire Dales is now found over a wide area of the Yorkshire Ouse floodplain (Hudson-Edwards and others 1999). Similarly, rising ground water in abandoned coal mines can release contaminants into groundwater and, in extreme cases, pollutes the soil. Acute pollution may also happen when heavily contaminated soils are disturbed, for example during building, landslides, and by erosion or dredging of estuarine and offshore sediments.

Ochre being released into a stream from old iron workings.

Peter Wakely/English Nature 8,189

Mick Murphy/English Nature

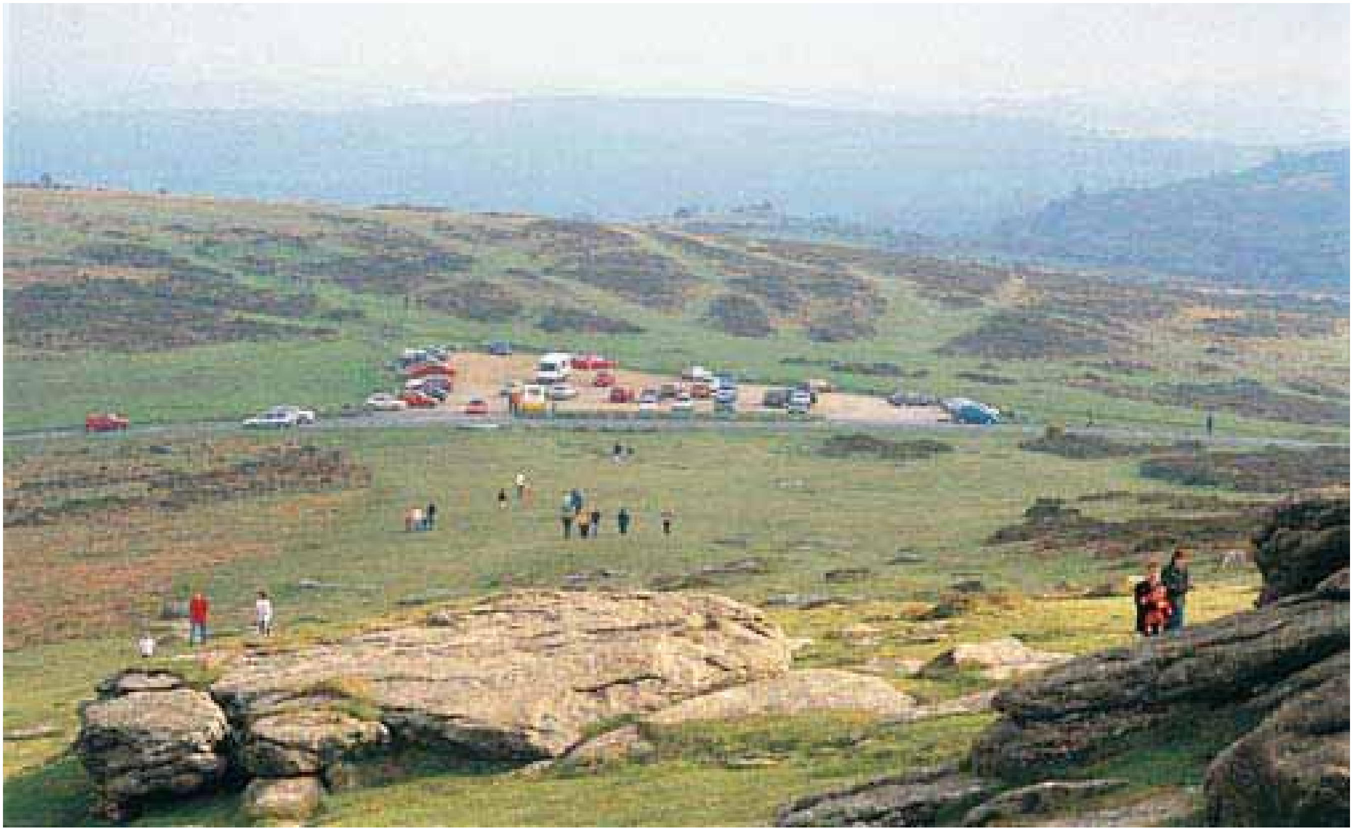
Interpretation panels, such as this one at Hunstanton, help to make visitors more aware of their geological heritage.

6.4 Taking geodiversity for granted

Failure to appreciate the value of our geodiversity, and its non-renewable nature, can be a major cause of loss and damage. Rocks, fossils and minerals have been formed over millions of years and represent unique past environments and events. The landforms around us have been produced over hundreds of thousands of years and soils may take several thousand years to form. Once lost, our geology, geomorphology, landscape and soils, are in many cases, simply not replaceable.

Few people are aware of the relevance of geodiversity to everyday life and the importance of conserving and respecting these assets. Whilst many people appreciate landscape and coastal scenery, few make the connection with the conservation of geology, landforms and landscape. Similarly, they may be interested in searching for fossils and dinosaur footprints but have very little understanding of other aspects of geology. Whilst rocky coastlines and mountains are valued for their natural beauty, man-made exposures such as quarries, gravel pits and mines can be seen as 'damaged' areas in need of restoration. Poor use of our understanding of natural geological processes can lead to inappropriate river management and coastal defences resulting in obscured geological features, damaged and changed landscapes, disrupted natural processes and the transference of erosion problems to other areas.

Public support is essential in all forms of conservation including geodiversity. Geodiversity must be promoted as part of our local heritage and culture, as a vital resource for education and learning and as a link between the character of our landscape and our environment. Popular media has an important role to play in raising the profile of geodiversity and encouraging people to value and respect it. The success of Sir David Attenborough's 'Life on Earth' series and other wildlife, geology and landscape programmes have demonstrated the interest that can be generated and raised peoples' perception of the finite nature and value of geodiversity.



Paul Glendell/English Nature 24,248

Tourist pressure at Haytor, Dartmoor National Park.

Recreation

Geodiversity attracts visitors. Whether in spectacular upland landscapes or dramatic coastal scenery, geodiversity is central to why people visit the countryside. However, recreational activities can have detrimental impacts, which need to be managed. In sensitive upland landscapes recreational damage can be persistent and slow to heal. Walking, especially off footpaths, can damage and potentially destroy vegetation, exposing soils to erosion. Where this occurs on steep slopes, or in areas of heavy rainfall, it can lead to significant gullying, causing loss of soil and visual scars on the landscape. This can be exacerbated where recreational activities include the use of mountain bikes, motorbikes, all-terrain vehicles and horses. Recreational damage to geodiversity is, however, relatively minor, when compared with the large-scale destruction that major developments can cause.

Cave systems are particularly sensitive to damage from recreational use including trampling, erosion, physical damage to cave features, and changes in moisture and light levels. Many caving societies are now actively involved in the conservation and monitoring of caves, so these incidents are increasingly rare.

Fossil and mineral collection

"Collecting seems to meet an innate human need" (Gray 2004). Fossils and minerals are a key part of our natural heritage and form a major scientific, educational and recreational resource. Collecting for scientific research increases our understanding of geology, especially where specimens are well documented and lodged in accessible public collections. Responsible collecting for enjoyment provides people with a stimulating experience of the natural world, improves their understanding and appreciation of geology and can contribute to science through the discovery of significant finds. This is especially the case where the fossil resource is extensive and subject to high levels of natural or artificial degradation, as in eroding cliffs or active quarries, where specimens can be lost if not collected.

Responsible fossil collecting

Many people visit the Jurassic Coast in Dorset and enjoy fossil collecting on the foreshore. Charmouth Heritage Coast Centre has developed a Fossil Collecting Code, supported by a Fossil Register, to encourage responsible collection.

Charmouth Fossil Collecting Code

- The best and safest place to look for fossils is on the beach where the sea has washed away the soft clays and mud.
- Beware of tides, cliff falls and mudflows, especially during wet and stormy weather. The best time to go collecting is when the tide is going out.
- **Subject to the detailed provisions of the code, fossils are not to be collected from the cliffs** without the permission of the landowner. If you do find a fossil in the cliffs, you must seek permission to extract it. The Charmouth Heritage Coast Centre can provide landowners' contact numbers.
- Take care if using a hammer – safety goggles are recommended.
- Consider how your actions may influence or affect those with less experience and remember, not everyone is here to find fossils.
- Tell someone where you are going and what time you expect to return.

Two categories of fossils are to be recorded in the Register of Important Fossils kept at the Charmouth Heritage Coast Centre:

Category I, key scientifically important fossils, includes new species or those specimens which may represent new species, fossils which are extremely rare (such as the Charmouth dinosaur *Scelidosaurus*) and fossils that exhibit exceptional preservation.

Category II, fossils of some (but not key) importance, include vertebrates such as reptiles or fish, partial or complete, especially where the horizon of origin can be identified. Nautiloids and certain ammonites together with unusual assemblages of fossils are also included.


Colin Prosser/English Nature

Portland Stone, Dorset.


Mick Murphy/English Nature

Irresponsible collection of minerals at Hope's Nose, Torquay.

However, where there is a clearly limited resource, the collecting of rocks, fossils and minerals can be damaging. For example, restricted resources such as mineral veins or fossil cave deposits are easily damaged or exhausted. Collecting without proper recording and curation, inexpert collecting, over-collecting and inappropriate use of power tools and heavy machinery are likely to reduce or even destroy the scientific value of such sites.

Collecting must be tailored to the available resource, and carefully managed to ensure the resource remains available for future generations (Townley 2003). However, most locations, especially eroding coasts and active quarries, have an extensive resource of geological specimens and responsible collecting here is an important part of conservation.

7 Opportunities to conserve geodiversity

The preceding chapters have described the diversity and historical significance of England's geology and landforms, how soils link geology with surface habitats and species, and how human activity has combined with these elements to forge the nature and character of the English landscape; the range of underlying geology, soils, natural processes and landforms that we collectively refer to as geodiversity.

These chapters have also summarised the measures we currently take to protect England's geodiversity against the range of threats to which it is subject. The findings of this report suggest that we are now close to achieving a coherent, integrated approach to protecting our natural resources – one that must include geodiversity at its core – an important step towards delivering sustainable development. However, much remains to be done.

This chapter outlines where our future priorities lie:

- Integration through landscape.
- Conserving geodiversity in protected areas.
- Making the right policy decisions based on sound science.
- Establishing clear performance indicators.
- Gaining public support and involvement.

Serpentine Cliffs, Kynance, The Lizard.

Pat Sargeant

Mick Murphy/English Nature

To address these priorities, we need to establish a clear programme of joint work with key partners as a foundation for future action. *Natural England*, which brings together English Nature, the Rural Development Service and the Countryside Agency's Landscape, Access and Recreation Division, will take this process forward as part of its new, integrated approach to working with and managing England's natural environment.

Integration through landscape

There is still a tendency to treat the elements of geodiversity separately, using different, and sometimes contradictory, legislative and policy frameworks. This has often been compounded by a historical focus on protecting sites (such as SSSIs) which, while clearly important, has meant we have paid less attention to changes taking place in the wider landscape – the dynamic setting of our everyday lives. The Convention on Biodiversity and the European Landscape Convention both call for a more integrated approach to the conservation of natural resources and landscapes, both within and beyond protected areas.

To help achieve a more integrated approach, Landscape Character Assessment has been developed to help inform cross-sectoral planning, design and management decisions that affect the wider landscape. It provides a basis for ensuring that landscape, land use and conservation policies reflect the capacity and sensitivity of landscape to cope with climate change and the impact of development.

Bringing together all interests through landscape allows us to make better-informed planning and management decisions and, consequently, ensures better outcomes for geodiversity. The value of this integrated landscape approach is also recognised by ecologists, who are adopting a more holistic approach to managing ecosystems – an approach that can better address the problems caused by the loss, fragmentation and degradation of habitats. This ecosystem management also acknowledges the importance of geodiversity, especially soils, in maintaining biodiversity within the wider landscape.

This integrated approach, with geodiversity at its core, is being extended into other areas. For example, the wider impacts of land management, particularly across whole river catchments, are increasingly recognised as influencing both the quality of river water and flood control. There are now several integrated land management schemes being piloted in defined catchments across the country. On the coast, Integrated Coastal Zone Management, and the use of Shoreline Management Plans, now involve relevant stakeholders in the shift from traditional coastal defence to more holistic coastal management as a response to rising sea level. Also, the development of Local Geodiversity Action Plans (LGAPs) is providing a new and integrated way of undertaking geological conservation beyond the more traditional, site-based focus.

Rocks at Masson Hill, Derbyshire.

Peter Wakely/English Nature 9,166

Cheddar Gorge.

Geodiversity in protected areas

Although the conservation of geodiversity in the wider landscape will become increasingly significant, its conservation within protected areas will continue to be of major importance. There is a need to designate further protected areas, review boundaries that are subject to dynamic geomorphological processes (for example, the ever-changing coast), and establish positive management to ensure that these protected areas are maintained in good condition. Further action is also needed to address geodiversity problems in protected landscapes such as National Parks, Areas of Outstanding Natural Beauty and Heritage Coasts.

Many of the threats to protected areas arise from changes in land use and management, and considerable effort has been invested in developing policies to help counter these threats. This policy ‘framework’ continues to be strengthened with the introduction of international conventions, European Directives and with successive revisions of national policy guidance. There is inevitably a time lag, however, between the introduction of new policy and its translation into practice, particularly at regional and local levels. For this reason, there is a need to promote examples of good practice and effective land management, and to ensure that these examples highlight the importance of geodiversity.

Making the right policy decisions based on sound science

There is clearly a need to improve the collation and interpretation of existing research and information. Just as important is the need to ensure that this information is made freely available to, and understandable by, those who make decisions about policy, planning and management. Decision makers should be in a position to make better quality decisions, based on sound scientific knowledge, to bring about more sustainable outcomes for geodiversity. Where relevant information is not available to ensure confidence that the outcome is sustainable, the precautionary principle should be applied.

As well as making full use of existing knowledge, we must commission new research to fill in the gaps in our understanding. A central theme to current and future research is adaptation to change, in particular, landscape and environmental change within the context of global climate change, which is bringing sea-level rise, increasing storminess and the likelihood of more frequent winter flooding and summer drought. Two areas of research will have a major impact on our knowledge. First, we must look further at the evidence in the geological record to better understand and demonstrate how the environment has responded to past climate change. Second, we need to understand more fully how present day geomorphological processes respond to change. Together, improved understanding of these subjects will help us to making genuinely informed decisions about planning and developing future environmental policy.

Gordale Scar, Malham.

Peter Wakely/English Nature 19,650

Performance indicators

We need to identify indicators that set the standard for measuring geodiversity, and allow us to monitor changes by area and through time. The results of this monitoring can be used to show how the condition of geodiversity is central to the success or failure of sustainable development. Furthermore, such indicators can be used to raise awareness of the importance of geodiversity, and provide the basis for more effective 'State of the Environment' reports and other national or regional environmental assessments. Feedback from these indicators will also be fundamental to responsive and adaptive land management, alerting us to emerging problems so we can ensure that appropriate avoiding or mitigating action is taken.

Before we can develop indicators, however, we need to establish better baseline data. We already have effective information on the condition of geological and geomorphological SSSIs and we have established the Joint Character Areas as a key monitoring tool for the future (although there is, as yet, only partial uptake of more detailed scale Landscape Character Assessment). For soils, there is only limited information regarding their environmental value and condition. Consequently, there is a pressing need for further research if we are to develop a robust suite of indicators in this area.

Work to develop the Countryside Quality Counts (CQC) indicator of change has revealed that we lack a comprehensive, nationally-consistent, shared data set for many elements of geodiversity. There is a growing recognition that the inter – relationships and interdependences between the different elements of geodiversity are the key to understanding complex environmental changes. Some of these issues will be addressed for the next run of the CQC indicator in 2006 (covering the period 1999-2003).

Public support and involvement

Sustainable development can only be achieved with the involvement and support of the public. Geodiversity is important – it affects every aspect of our lives and its condition is central to the success or failure of sustainable development. However, many of us take it for granted, even in the most inspirational landscape setting. To help people appreciate the value and benefits of geodiversity we must encourage public access to Areas of Outstanding Natural Beauty, National Parks and other protected sites, and engage people in local initiatives that will raise their awareness of the environment and landscape in which they live. In doing this their appreciation of geodiversity and the value they place on it will increase.


Mick Murphy/English Nature

Rocks at Masson Hill.

Dave Evans/English Nature

Frodingham Ironstone rockstore established as a future fossil collecting resource, North Lincolnshire.

English Nature, the Countryside Agency and the Rural Development Service are already involved in initiatives designed to engage local people in projects to protect and conserve our natural resources, and so help to deliver sustainable development. Examples of these initiatives include work in the coastal environment, the England Rural Development Programme and in Landscape Character Assessment. At the same time, resources available for the conservation and promotion of geodiversity have increased, especially with the advent of the Heritage Lottery Funds and the Aggregates Levy Sustainability Fund.

Such grant initiatives have demonstrated the value that local communities place on support delivered at a local level. Better integration, however, of geodiversity objectives into schemes that deliver positive environmental and socio-economic outcomes is still needed. Not only will this directly benefit geodiversity, it will add value to existing initiatives. This would represent a more effective use of resources, and prove the value of an integrated approach to the sustainable future of our environment.

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Peter Wakely/English Nature 19,652

Gordale Scar, Malham.

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Glossary of abbreviations

ALSF	Aggregates Levy Sustainability Fund
Defra	Department for Environment, Food and Rural Affairs
GCR	Geological Conservation Review
HLF	Heritage Lottery Fund
LDUS	Landscape Description Units
LGAP	Local Geodiversity Action Plan
NATMAP	National Soil Map
NNR	National Nature Reserve
NSRI	National Soil Resources Institute
PSA	Public Service Agreement
QPA	Quarry Products Association
RIGS	Regionally Important Geological and geomorphological Sites
SAMSA	Silica and Moulding Sand Association
SMP	Shoreline Management Plan
SSSI	Site of Special Scientific Interest
STIPA	Sustainable Tourism in Protected Areas
UNESCO	United Nations Education, Scientific and Cultural Organisation

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Main: Red sandstone of the Staffordshire Roaches. Peter Wakely/English Nature 21,069