Geoconservation: principles and practice

Part 1 of 3

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Sections through gastropods preserved in the Late Jurassic Malton Oolite at Nunnington Cuttings and Quarries SSSI, North Yorkshire. ©Natural England/ Dave Evans

Geoconservation: Principles and Practice

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Rescue excavation of a large Lower Jurassic Ichthyosaur on the foreshore in Bridgwater Bay National Nature Reserve, Somerset. ©Geckoella Ltd reproduced with permission

Clearance works to re-expose the Middle Jurassic Cornbrash Formation at Thrapston Station Quarry SSSI, Lincolnshire. ©Natural England/Dave Evans

Demonstrating geoconservation at Wren’s Nest National Nature Reserve, Dudley, West Midlands. ©Natural England/Colin Prosser

Site investigation to determine the location and distribution of the geological interest at Teffont Evias Quarry / Lane Cutting Site of Special Scientific Interest, Wiltshire. ©Natural England/Dave Evans

Section of the dry valley at Lathkill Dale National Nature Reserve, Derbyshire.
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Foreword

Geodiversity is an integral part of the natural environment and has an important role to play in nature recovery. It underpins and defines the character and distribution of England's varied and locally distinctive landscapes, influences the nature and distribution of habitats and species, and has shaped the character and cultural identity of the different parts of the country.

England is extremely geodiverse with many geological and geomorphological features, processes, sites, and landscapes of international, national, and local importance to science, education, and society. Its importance is reflected in the geoheritage represented in England's suite of Local Geological Sites, Sites of Special Scientific Interest (SSSI), National Nature Reserves (NNR), UNESCO Global Geoparks and the Jurassic Coast World Heritage Site (WHS). These special places enable us to study and understand how the Earth works, for example the nature and frequency of natural hazards, and contain fossils which enable us to study and understand the evolution of life and how it has responded to, and recovered from, past climate change and major extinction events. Geological sites also enable us to build the knowledge we need to locate and recover the natural resources on which society depends, such as water, metal ores and building stone. Conserved and well managed geoheritage provides a wide range of social and economic benefits, for example through generating geotourism and related businesses. It also provides spectacular and inspirational backdrops that define many popular landscapes, such as National Parks, Areas of Outstanding Natural Beauty, Heritage Coasts and views from the England Coastal Path, whilst the Jurassic Coast WHS and UNESCO Global Geoparks have been shown to generate significant income and employment for their local communities. Importantly, geological features associated with past mining and industrial activity regularly occur in urban settings, providing unique opportunities for education, community engagement and recreational use in places where people live and work.

Geoheritage, like all elements of the natural environment, is subject to a range of anthropogenic and natural threats and action is required to conserve, recover, and enhance it. Natural England, with its statutory duty to conserve nationally and internationally important geological and geomorphological sites and features, primarily through the SSSI and NNR series, plays a major role, as the SSSI series is the backbone of geoconservation in England. The importance of this site series is recognised by the Government with Indicator G2, of its 25 Year Environmental Plan, requiring regular reporting on the condition of designated geological/ geomorphological sites.

Geoconservation is a team effort, however, and bodies managing UNESCO Global Geoparks and the Jurassic Coast WHS, local geological and geoconservation groups, landowners and occupiers, local authorities, charities such as the National Trust, developers, the mineral extraction industry, planning consultants, engineers and academic geologists all have an important role to play.

This review of the practice of geoconservation builds upon and updates that set out in Geological conservation – a guide to good practice published by English Nature in 2006. It draws upon seventy years of practical experience of Natural England and its predecessor bodies as well as that of many partners and stakeholders. It provides context for geoconservation but most importantly focuses on the principles and practice of delivering geoconservation on the ground. It illustrates challenges, opportunities, threats and successful approaches using actual case studies, both old and new, and illustrating what might work and what might not. Although primarily written to support geoconservation in England this review should also be of relevance and interest to anyone interested in conserving, recovering or enhancing geodiversity anywhere in the World.

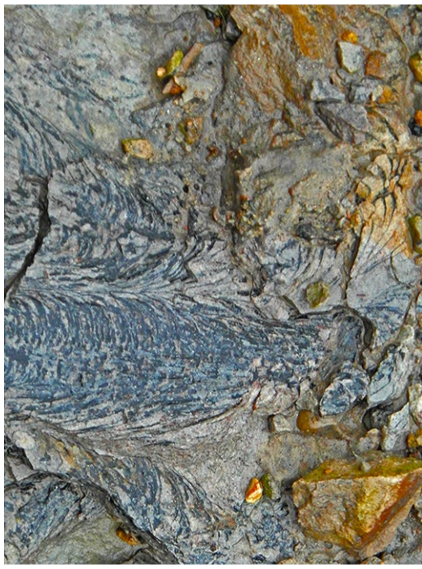
Dave Evans, Eleanor Brown, Jonathan Larwood, Colin Prosser, Barbara Silva, Hannah Townley & Anna Wetherell

Downton Gorge National Nature Reserve, Herefordshire. River Teme in full flow. Late Silurian sediments forming cliffs of gorge. ©Natural England/Dave Evans

Chapter 1: Why conserve geodiversity?

1.1: What is geodiversity?

‘Geodiversity’ is the abiotic equivalent of ‘biodiversity’ and is defined as “the natural range (diversity) of geological (rocks, minerals, fossils), geomorphological (landforms, topography, physical processes), soil and hydrological features, including their assemblages, structures, systems and contributions to landscapes” (Gray, 2013).



Brymbo Fossil Forest, Wrexham/Wrecsam, Wales. Branches and leaves of *Lepidodendron*, part of a diverse and exceptionally preserved assemblage of Late Carboniferous plants providing a window into an ancient terrestrial ecosystem. ©Natural England/Hannah Townley

1.2: Why is geodiversity important?

Geodiversity is of great scientific, cultural and educational importance, providing us with a means of not only studying and understanding the history of our planet and the evolution of life, but also understanding the formation and development of the solar system. It provides a record of billions of years of Earth history, enabling us to understand how our planet formed and evolved, how continents have drifted, the evolution and extinction of life, changing climate and sea-level, and how natural processes such as volcanism, mountain building, coastal erosion and soil formation have shaped and continue to shape the landscape and natural world around us.

Folded banded cherts at Newborough Warren, Anglesey/Ynys Môn, Wales. These sediments were deposited on an ocean floor that was subsequently incorporated in an accretionary complex derived from the collision of an oceanic ridge with a trench about 550 million years ago. ©Natural England/Colin Prosser

In addition to its intrinsic value, geodiversity, like biodiversity, drives and supports many ‘ecosystem services’ on which society depends. These include flood regulation, habitat provision, the shaping of landscape character, artistic inspiration and opportunities for geotourism as well as scientific, educational and recreational opportunities. Of increasing importance is the understanding of past climate and environmental change, and the linked responses of natural systems. These can be determined from studying geodiversity. Such long-term perspectives provide a context for managing change and enable us to plan suitable environmental adaptation strategies.

Access to geodiversity in order to record, study, and interpret its associated features is, therefore, essential for scientific study and education. Such access is also essential to facilitate the training of the geoscientists needed to find and supply the natural resources, (including minerals, building stone, hydrocarbons and water) on which society depends, as well as identify, predict and manage hazards (e.g. earthquakes, landslides, subsidence, flooding) that can have major impacts on communities at a variety of scales.

In the UK, geodiversity is particularly diverse and visually impressive. It contains representatives of all the major divisions of geological time. It illustrates a wide range of rock types, structures, natural processes and landforms, as well as yielding an outstanding array of fossils and minerals. The UK was a major pioneer in the development of the science of geology, and geosites, both natural and man-made, have played a key role in the development of geoscience and continue to be important today. Consequently, numerous internationally recognised divisions of geological time have been named and defined from UK strata and many geological sites in the UK are of international significance.

The Jurassic rocks of the Dorset and East Devon Coast World Heritage Site provide the foundation for dynamic, spectacular and iconic coastal scenery. These rocks continue to contribute to the study of Jurassic environments. Below Golden Cap, blocks of sandstone from the Three Tiers, rest on clays of the Green Ammonite Mudstone Member. ©Natural England/Hannah Townley

Trench opened into Bed 10 of the Peterborough Member (Oxford Clay Formation) at Must Farm, Whittlesey, near Peterborough. The Oxford Clay of Eastern England continues to yield the fossil fishes and marine reptiles that have been studied for over 150 years. ©Natural England/ Naomi Stevenson

1.3: Why conserve geodiversity?

Geoscience is essentially a field-based subject. The existence of well exposed geological and geomorphological features, as well as naturally functioning geomorphological and soil processes are critical, for example, for scientific study, educational and recreational use and the provision of a range of other ecosystem services.

Accessible and well managed features and sites are required for the advancement of geoscience, as well as for the demonstration of the principles of geology and the processes of landscape evolution. Such sites (referred to throughout this handbook as **geosites**) act as a resource to train geologists and engineers, as well as a recreational and tourist resource for those interested in the natural environment. Consequently, it is necessary to conserve geodiversity so that it remains available for future study, use and enjoyment.

Disused ironstone workings at Finedon Top Lodge SSSI, near Wellingborough, Northamptonshire. Clearance works reveal coloured mudstones of the Middle Jurassic, Rutland Formation. This gives a clear demonstration of the effects of talus build-up and vegetation growth on the extent and quality of exposure. ©Natural England/ Mick Murphy

1.4: Who benefits from geoconservation?

Many organisations, public bodies, societies, industries, communities and individuals benefit from geoconservation. These include

- Those involved in geoscience research, seeking to understand the Earth and the environmental changes, including climate change, that impact on it
- Geoscientists and other professionals working in those industries seeking to find, utilise and manage our mineral and water resources, or manage the natural environment around us
- Land owners, land managers, public utilities, planning authorities and others, who require some understanding of geoscience and geodiversity in order to better inform their decisions and action
- Ecologists and those involved in nature conservation more generally, who need some understanding of geoscience and geodiversity, to help, for example, in planning habitat re-creation projects
- Universities and schools that need well-exposed sites for fieldwork
- Amateur geoscience societies and groups that enjoy fieldwork in their leisure time
- The general public who may enjoy geodiversity for recreational or educational purposes or as a source of artistic inspiration
- Society, through Geodiversity as a natural capital asset and ecosystem services provided by geodiversity such as buffering

The extensive faces at the disused Shipton-on-Cherwell Cement Works SSSI (Oxfordshire) once exhibited rapid lateral facies changes in the Middle Jurassic sediments they exposed. Stabilisation of the faces in order to prepare the site for redevelopment has resulted in the loss of the bulk of these exposures, leaving only isolated windows. ©Natural England/Dave Evans

from flooding and coastal erosion provided by naturally functioning geomorphological processes

- Communities in geologically interesting, unusual or spectacular areas that benefit from geotourism based on local geodiversity and landscape

1.5: What is geoconservation?

It is only in visible exposures such as coastal cliffs and foreshore, inland outcrops, quarries, cuttings and river sections that we can actually see and study the geological record. A major threat in terms of their geological conservation arises from proposals that could result in their burial. Activities that are likely to lead to the burial of these exposures include coastal management schemes, stabilisation works or landfill. This is especially likely where exposures are located on eroding coastal cliffs or in quarries.

Road cutting on the A690 north of Dalton-in-Furness, Cumbria. Rock fall netting can have severe impacts on both visibility and accessibility of geodiversity, promoting vegetation growth behind the netting. ©Natural England/Dave Evans

Geomorphological features are even more vulnerable to damage than geological exposures because they usually need to be conserved in their entirety. Landforms were either created in the geological past (e.g. by the action of ice during glaciations) or are still being shaped by ongoing processes (e.g. rivers and coastlines). A geomorphological feature created by past processes, over long periods of time, is clearly vulnerable to damage, as it cannot be recreated or replaced if damaged or destroyed. An active geomorphological feature is also very sensitive to interference, and can easily be damaged or destroyed if the processes on which it depends are modified.

In summary, whilst many geodiversity features and geosites are relatively robust when (compared to some species and habitats), they are subject to a range of anthropogenic and natural threats. Within the UK, significant threats include:

- Loss of geological exposure through burial under coastal protection schemes, landfill or other developments, such as infrastructure and housing.

- Loss of geological exposure as a consequence of vegetation encroachment.

- The removal of irreplaceable features such as caves, landforms or finite deposits of fossils or minerals through quarrying.

- Removal and loss to science of fossil or mineral specimens through irresponsible collecting.

General neglect can have significant impacts on the extent and visibility of exposure, particularly on soft sediment sites. Bolter End Sand Pit SSSI (Berkshire) provides exposures of the Palaeogene Reading Formation in gravel dominated facies. Long-term collapse of the faces and the growth of vegetation means that the original exposures are now obscured. Any future research on the site will require extensive and costly re-excavation. ©Natural England/Dave Evans

- Damage to geomorphological features or processes, for example, as a result of coastal protection or river management schemes.

- Ignorance of the importance of geodiversity and the need to conserve it.

Geoconservation can therefore be defined as 'action taken with the intent of conserving and enhancing geological, geomorphological and soil features, processes, sites and specimens, including associated promotional and awareness raising activities and the recording and rescue of data or specimens from features and sites threatened with loss or damage.' (Prosser, 2013).

It is important to appreciate that the objective of geoconservation is to conserve rather than preserve. Conservation facilitates continuing scientific and educational usage of the resource, whereas preservation implies that the resource is completely protected from further depletion. Emphasis is placed on the management of a particular feature in order

Beach hut development at the foot of the cliff to the west of Branscombe Chine, Branscombe, East Devon. The impacts of the development on cliff erosion are evident from the contrasting extent of talus accumulation and vegetation growth between the developed and undeveloped strips of the foot of the cliff. ©Natural England/Dave Evans

Conservation Enhancement Scheme at Cliff Farm Pit SSSI, Lincolnshire. (Left) before (right) after. ©Natural England/Dave Evans

to sustain a particular ‘quality’ through regulating processes that affect changes in the ‘quality’, rather than on inhibiting any change at all. There are rare cases, however, when the geodiversity resource is so finite and limited in extent, that some degree of preservation may be necessary.

Legislation in the UK has led to a site-based approach to the conservation and management of geological and geomorphological sites and features. Their selection is largely based on scientific and educational importance. In contrast, soil conservation has been largely driven through

Unconformity between Lower Jurassic rocks and the Cretaceous at Rifle Butts Quarry SSSI, protected from rainfall by a shelter. ©Natural England/Dave Evans

a sustainable resource management approach based on agricultural, rather than scientific or educational, value. This document is primarily focused on the conservation of geological and geomorphological features, sites and processes and as such on the practicalities of site-based conservation.

Rescue and record approach for significant and threatened finds. This plesiosaur would be lost to the sea if left *in situ*. It was extracted and conserved and is now on exhibition. ©Somerset Heritage Centre/Dennis Parsons reproduced with permission

Ardley Cutting and Quarry SSSI and Ardley Trackways SSSI, Oxfordshire contain Middle Jurassic sediments preserving a complex of sauropod and theropod trackways (here exposed in the foreground). Planning conditions for quarry extensions ensure that extraction will cease above the level of the trackways. This means that they can be conserved in the restoration until such a time that they can be studied and/or be exhibited under a protective cover. ©Natural England/Dave Evans

Middle Jurassic, cross-bedded oolites at Swaddywell Pit, a Local Geological Site near Peterborough, Cambridgeshire. ©Natural England/Dave Evans

Chapter 2: Conserving geosites

2.1: Introduction

The conservation of geosites can be considered as a three stage process:

- site audit and selection
- site designation through a statutory or non-statutory framework, and
- site safeguard, management, and promotion

The main focus of this document is on safeguard and management, but other aspects of the process are also considered briefly in this chapter, including the planning system and development on geosites as well as how climate change may affect them.

2.2: Site audit and selection

The site audit and selection stage is fundamental to the whole process of geoconservation. There should be a definite strategy underlying the audit and selection process in order to obtain a robust site coverage which is defensible against the challenges and threats faced by sites (Reynard & Brilha, 2018).

In the UK, The Geological Conservation Review (GCR) is a pioneering example of an audit and selection process. The main phase of the GCR is undertaken in Great Britain between 1977 and 1990 to identify a large suite of sites suitable for designation as statutorily protected Sites of Special Scientific Interest (SSSIs). The purpose of the GCR was to systematically identify the key geological sites in Great Britain. The series as a whole reflects the great range and diversity of British geology. Responsibility for coordination of the GCR lies with the government conservation agencies and the results of the GCR are now published through the *Proceedings of the Geologists' Association*. The GCR is described in detail by Ellis *et al.* (1996) and Ellis (2011) and is set out in a wider geoconservation context in Prosser et al. (2018).

GCR sites are selected on the basis of their scientific value. Three criteria are applied in selecting the GCR sites:

- sites of international geological importance
- sites that are scientifically important because they contain exceptional features, and
- sites that are nationally important because they are representative of a geological feature, event or process, which is fundamental to understanding Britain's geological history

Avon Gorge SSSI from the Clifton Suspension Bridge, Bristol. Showing part of the extensive exposures of the Dinantian carbonate succession of the Mendip Shelf. The classic exposures in the Avon Gorge GCR site have played a significant role in the study of early Carboniferous stratigraphy in the UK. Note the range of infrastructure associated with the site – all of which may impact on the management of these exposures. ©Natural England/Dave Evans

Brimham Rocks SSSI, Yorkshire. Carboniferous sandstones (Millstone Grit) were weathered into tors during the Pleistocene. The site preserves a range of features that provide evidence of the nature of the weathering processes to which these rocks were subjected. ©Natural England/ Hannah Townley

Assessment and subsequent selection of sites was undertaken on the basis of a series of subject 'blocks' which are based on divisions of geological time, subject, regional divisions or combinations of these. Examples of GCR blocks include Precambrian of England and Wales, Mineralogy of the Lake District, Cambrian, Aalenian-Bajocian, Marine Permian, Tertiary Mammalia, Quaternary of South-West England, Caves of Great Britain and Karst of Great Britain.

Portland Bill SSSI, Isle of Portland, Dorset. Pre-Ipswichian and Ipswichian raised beach deposits rest on a relict wave cut platform at a height of several metres above present sea-level. ©Natural England/Jonathan Larwood

Sites are selected in consultation with academic experts in the various specialist fields. Large numbers of sites are considered but, in general, only one site is selected as the best example of each aspect of geology under consideration. Once selected, a GCR site is then proposed as a potential SSSI for approval by the relevant government conservation agency (see Section 2.3). In England, it is only when a site is approved as a SSSI by Natural England's independent Board that it receives full legislative protection.

While the main phase of the GCR process formally ended in 1990, there has been some ongoing review of the site coverage for a number of reasons. Firstly, geoscience is dynamic and new scientific understanding may require modification of the original site coverage. Secondly, new sites may be discovered which were not known at the time of the original audit and these may be superior to existing sites. Thirdly, if interest features on a site become damaged or destroyed, there may be a need to find a replacement site.

View across Castleton SSSI, Derbyshire from Odin's Mine to Mam Tor. This includes four GCR sites that cover Dinantian Stratigraphy, Namurian Stratigraphy, Mineralisation, and Mass Movement. ©Natural England/Dave Evans

Aldeburgh Hall SSSI, Aldeburgh, Suffolk. Exposures of the Pliocene, Coralline Crag have been re-exposed for study after being obscured by talus and vegetation. ©Natural England/Mick Murphy

In Great Britain, site audits are also undertaken on a local or regional level and may subsequently result in sites being designated as Local Geological Sites (LGS) which are also sometimes known as Regionally Important Geological and Geomorphological Sites (RIGS). There are a many areas where county level audits have been undertaken for the selection of LGS. Site audits are also an important part of the Geodiversity Action Plan (GAP) process (Chapter 5).

In contrast to GCR sites which were selected purely on their scientific importance, there is a wider range of criteria to be taken into consideration in selecting LGS:

- Education - the value of the site for educational purposes in life-long learning
- Research - the value of the site for study by both professional and amateur Earth scientists
- Historical - the historical value of the site in terms of important advances in Earth science knowledge, events or human exploitation
- Aesthetic - the aesthetic value of the site in the landscape, particularly in relation to promoting public awareness and appreciation of Earth sciences

The existence of a well-defined rationale behind site selection provides an important tool in conserving sites should they be subject to development or other pressures. For example, a site may not possess spectacular geology but it may represent a vital part of a network of sites, and the loss of the site may be detrimental to the network and the understanding of

Fossil collecting at Kings Dyke Brickpit LGS, Whittlesey, Cambridgeshire. Waste material from the base of the Oxford Clay Formation is used to provide a fossil collecting area and resource for local schools and visitors to Kings Dyke Nature Reserve. ©Natural England/ Colin Prosser

geology as a whole. This type of argument is frequently used in protecting geological SSSIs from development.

Memorial Crags GCR site, part of Bradgate Park and Cropstone Reservoir SSSI, Leicestershire. Deep-water volcano-clastic successions exposed here are of international importance for their assemblages of Ediacaran (650-541 million years ago) organisms. These features are particularly sensitive to recreational activities, vandalism and attempts to collect specimens. ©Natural England/Mick Murphy

2.3: Legislation and SSSI designation

In Great Britain, the primary statutory mechanism for protecting a nationally and internationally important geosite is designation as a Site of Special Scientific Interest (SSSI). The background to this legislation is outlined in Appendix B.

It is only when a site is approved as a SSSI that it receives full legislative protection. There are about 1150 geological SSSIs (c. 30% of the total number of SSSIs) in England. Only sites selected by the GCR are designated as SSSIs. GCR sites have no formal legal protection before they are notified as SSSIs. Designation as a SSSI provides a high degree of protection for sites. In England, as part of the designation process, site owners and occupiers are informed of the importance of their land and provided with a generic list of operations requiring Natural England's consent (a list of activities which many cause damage to the interest features). If a site owner or occupier intends to undertake or allow any of these activities, formal consent must be sought from Natural England. Failure to do so can result in the owner or occupier being required to rectify any damage at their own expense and can lead to prosecution. If Natural England refuses consent for an activity, the owner or occupier has the right to appeal to the Secretary of State for the Environment.

In England, Natural England is a statutory consultee on any planning proposal which may affect a SSSI. This allows Natural England to

Wasdale Screes GCR site and SSSI, Cumbria. A classic geomorphological locality for screes, and considered to have been the product of gradual mass wasting processes, recent work suggests that they might instead have originated from the catastrophic failure of deeply fissured blocks forming the crest of the ridge. Such work demonstrates the continuing scientific value and importance of conserving these sites. ©Natural England/Hannah Townley

Proposals by the Planning Authority to place rockfall netting over the Pleistocene fossil cliff forming the Black Rock GCR site (Brighton to Newhaven SSSI, Sussex) were objected to by Natural England and the geological community. The outcome of the subsequent Public Inquiry was that netting could not be used. ©Natural England/Dave Evans

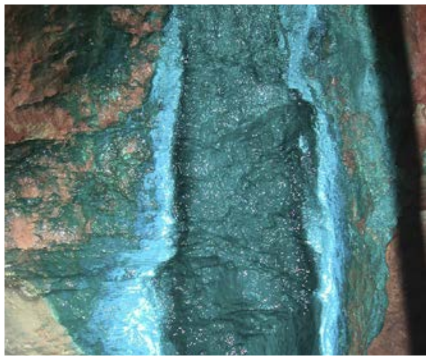
comment and, if necessary, object to development proposals which could adversely affect a SSSI. Early consultation, prior to submission of any plans, is preferable so that the developer has a clear idea of what may or may not be acceptable. This also provides an opportunity to work out acceptable solutions at the pre-submission stage which is likely to be more cost effective than having to redraft plans later.

If no compromise or resolution can be achieved, a public inquiry may be called. This can be an expensive process for all parties involved and is only undertaken as a last resort. There have been some high profile public inquiries on coastal geological sites in England that have set precedents for developing strategies and approaches that can achieve positive conservation outcomes (see the Birling Gap case study in Chapter 4).

Damage to SSSIs by third parties is also covered in the legislation. Prior to the Countryside and Rights of Way (CRoW) Act 2000, the legislation was weak in relation to third party damage, but there is now the power to prosecute third parties who knowingly cause damage to SSSIs. Third party damage can be deliberate or inadvertent and includes irresponsible collecting, vandalism (such as graffiti), destruction of features (such as damaging cave formations) and erosion and damage through over- or inappropriate use (such as path erosion, mountain biking and off-road driving).

Local or regional conservation designations for geology are generally

Secondary copper minerals coating the wall of an adit in Engine Vein Mine, Alderley Edge SSSI, Cheshire. ©Natural England/Hannah Townley



called Local Geological Sites (Section 2.2). LGSs have no statutory protection, but many local planning authorities, on the advice of the LGS group, include these sites within their local development plan or within supplementary planning guidance. These plans usually have policies for the protection of LGSs and their importance is taken into account in making planning decisions.

2.4: Site safeguard and management

2.4.1: The Earth Science Conservation Classification (ESCC)

The Earth Science Conservation Classification (ESCC) is at the heart of geoconservation in England. The ESCC is used by all of the UK statutory conservation agencies as the basis for guiding site safeguard and management decisions.

The ESCC was developed in order to rationalise the practical approach to conservation of the various types of geological site. It was first described in the Nature Conservancy Council's strategy document for geoconservation (Nature Conservancy Council, 1990a), revised in 2006 (Prosser and others, 2006) and set in an international context (Prosser et al. 2018).

The ESCC uses site type as the basic unit of classification (Table 2.1). The classification allows generic threats and conservation strategies to be defined for the different site types. For example, most disused quarries have

	Type of site	Site code
Exposure or extensive	Active quarries and pits	EA
	Disused quarries and pits	ED
	Coastal cliffs and foreshore	EC
	River and stream sections	EW
	Inland outcrops	EO
	Exposure underground mines and tunnels	EU
	Extensive buried interest	EB
	Road, rail and canal cuttings	ER
Integrity	Static (fossil) geomorphological	IS
	Active process geomorphological	IA
	Caves	IC
	Karst	IK
Finite	Finite mineral, fossil or other geological	FM
	Mine dumps	FD
	Finite underground mines and tunnels	FU
	Finite buried interest	FB

Table 2.1 The Earth Science Conservation Classification

similar generic conservation issues associated with them, which are quite distinct from the issues on most coastal sites and are explained below.

In the ESCC, there are 16 site types divided into three major categories: exposure or extensive (E), integrity (I) and finite (F). The distinctions between the three main categories are important, reflecting fundamental differences in conservation strategies.

Exposure or extensive (E) sites contain geological features which are relatively extensive beneath the surface. The basic principle is that removal of material does not cause significant depletion of the resource, as new material of the same type is being freshly exposed as material is removed. The main management aim is to achieve and maintain an acceptable level of exposure of the interest features. The main threats are activities which result in long-term or permanent concealment of the geological interest features. These include landfill, building development and coastal protection. Vegetation management and removal of scree are important issues on many inland sites where erosion rates are too low to maintain fresh exposures.

Integrity (I) sites are all geomorphological and are often more sensitive than exposure sites. Holistic management is the key to conservation of integrity sites. The recognition that damage to one part of a site may adversely affect the whole site is important. For some integrity sites, such as active geomorphology sites or caves, it is essential to recognise the potential impacts that activities outside of a site may have on the interest features. Building development, coastal protection and quarrying are among the most serious threats.

Finite (F) sites contain geological features that are limited in extent so that removal of material may damage or destroy the resource. In some cases,

Breedon Cloud Quarry SSSI, Leicestershire. An exposure site and Active Quarry (EA) exposing a range of Carboniferous Limestone facies. Continued quarrying will maintain the interest features. ©Natural England/ Hannah Townley

Karst (limestone pavement) above Malham Cove (Malham-Arncliffe SSSI), North Yorkshire represents an integrity site (IK). Here, the features are sensitive to a variety of anthropogenic processes, such as quarrying, the use of fertilizers and other activities that might bring about irreversible change. ©Natural England/Hannah Townley

Puddlebrook Quarry SSSI, Forest of Dean, Gloucestershire. An example of a Finite Mineral (FM) site. Here a rare Dinantian plant assemblage is preserved in the floor of a channel (dark band in image). Its distribution is extremely limited and provides a good example of a finite site. ©Natural England/Mick Murphy

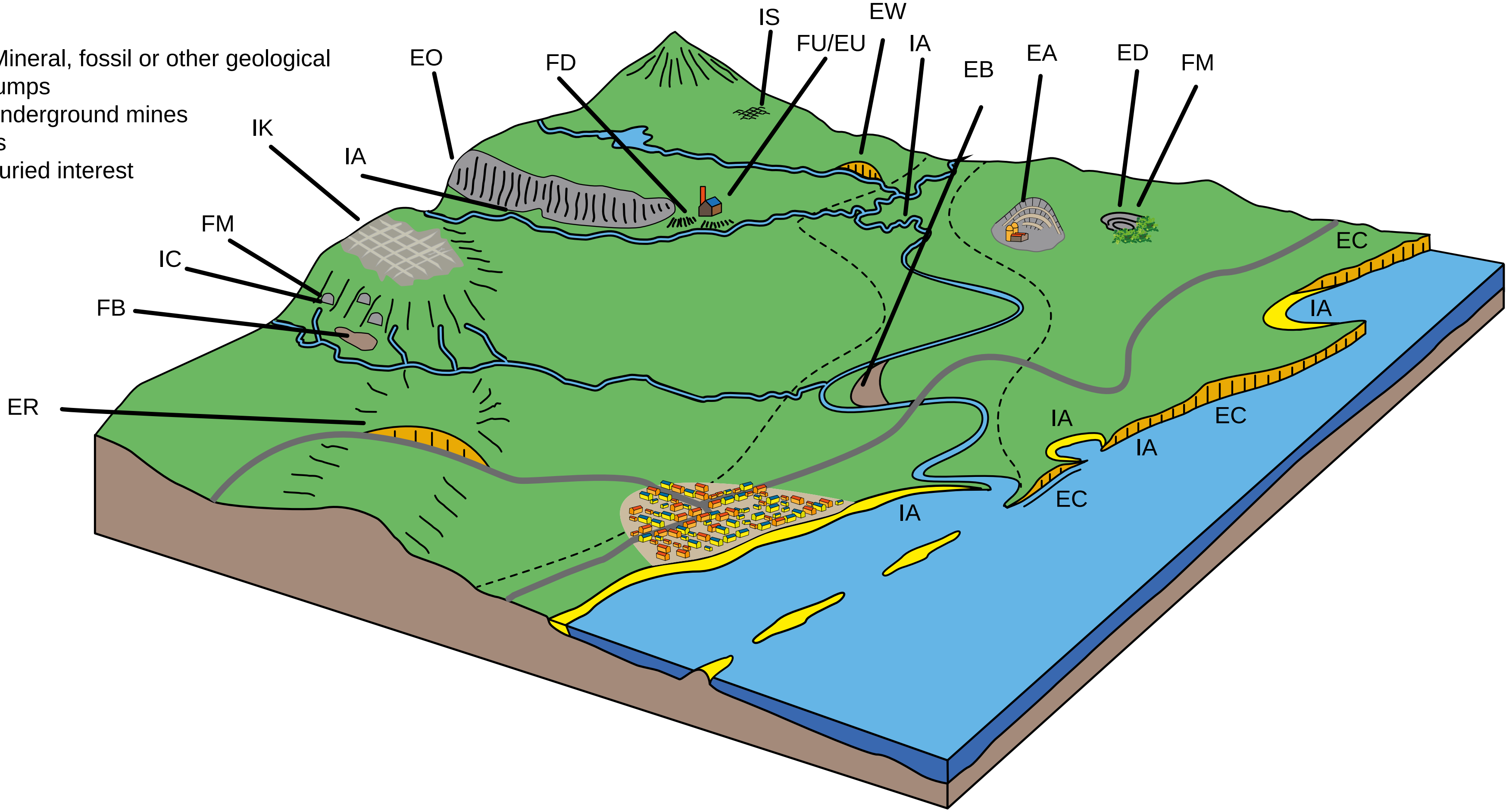
the features may be unique and irreplaceable. The basic management principle is to permit responsible scientific and educational usage of the resource while conserving it in the long-term. Irresponsible collecting can be a threat where the resource is finite and careful management of the removal of material may be necessary. Other threats include building development, coastal protection, and quarrying. Finite buried interest sites (FB) and finite mineral, fossil or other geological (FM) sites are similar and have many similar management issues, however, FM features are at least partially exposed at the surface, whereas FB sites are entirely buried.

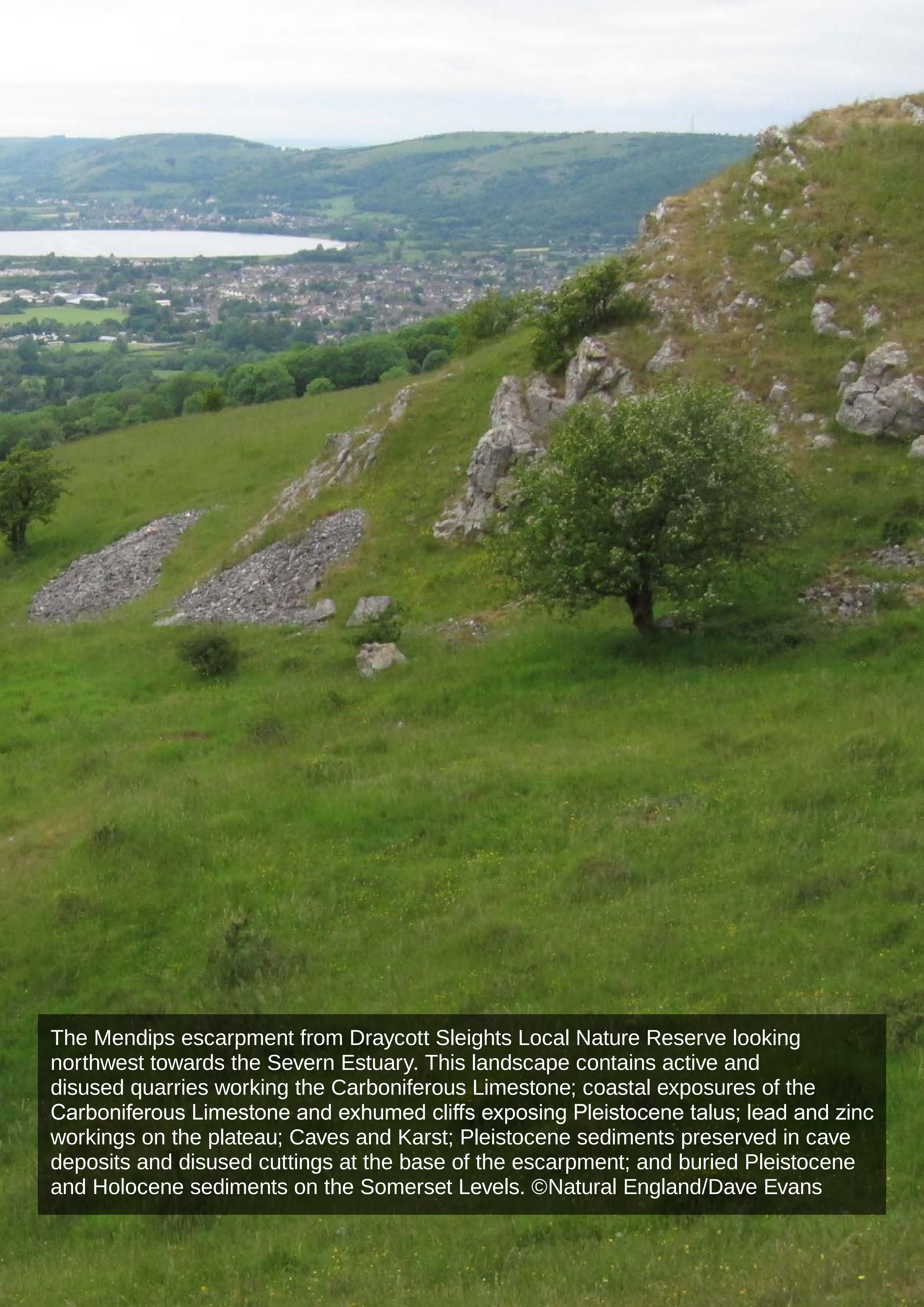
Sites may fall into more than one ESCC category. For example, a disused quarry with an exposure of stratigraphic interest would be classified as ED (Table 2.1), but localised mineral veins within the same site would have an FM classification.

Figure 2.1: Features in the Landscape

Features in the Landscape

EA Active Quarries
ED Disused Quarries
EC Coastal cliffs & foreshore
EW River & stream sections
EO Inland Outcrops
EU Exposure underground mines and tunnels
EB Extensive buried interest
ER Road, Rail and Canal Cuttings
IS Static fossil geomorphological
IA Active Process geomorphological
IC Caves
IK Karst
FM Finite Mineral, fossil or other geological
FD Mine dumps
FU Finite underground mines
and tunnels
FB Finite buried interest





The Mendips escarpment from Draycott Sleights Local Nature Reserve looking northwest towards the Severn Estuary. This landscape contains active and disused quarries working the Carboniferous Limestone; coastal exposures of the Carboniferous Limestone and exhumed cliffs exposing Pleistocene talus; lead and zinc workings on the plateau; Caves and Karst; Pleistocene sediments preserved in cave deposits and disused cuttings at the base of the escarpment; and buried Pleistocene and Holocene sediments on the Somerset Levels. ©Natural England/Dave Evans

Table 2.2: Geological site types with associated potential threats and issues and conservation techniques. Column 5 lists relevant case studies (Chapter 4).

	Type of site	Site code	Main potential threats and conservation issues
Exposure or extensive sites	Active quarries and pits	EA	• Maintaining access (in particular scientific) to geological features • Storage of quarry waste • Development on the quarry floor and adjacent to the quarry • Restoration • Landfill
	Disused quarries and pits	ED	• Landfill • Development on the quarry floor and adjacent to the quarry • Vegetation encroachment • Tree planting • Instability and slumping of faces • Flooding • Irresponsible specimen collecting • Fly tipping • Vandalism
	Coastal cliffs and foreshore	EC	• Coastal management • Development • Vegetation management • Dredging • Offshore renewable energy schemes • Irresponsible specimen collecting

Conservation Techniques	**Case Studies (Sites marked * were documented in Prosser *et al*., 2006)**
• Consultation with quarry operator to promote best conservation practice and gain ongoing access for scientific study and recording of temporary sections etc. • Early and ongoing consultation with planners and quarry operators to consider and promote geological conservation during and after the working life of the quarry • Include conservation sections and undug reserves within the restoration plan	• Barrington Chalk Pit and Broadway Quarry* • Briton's Lane Quarry • Clee Hill Quarries* • Frogden Quarry • Kings Dyke, Cambridgeshire • Philpot's Quarry
• Conservation voids or conservation sections above or adjacent to the landfilled area • Restrict development adjacent to and within quarry • Vegetation management • Avoid tree planting near geological features • Removal of rock debris and slumped material • Re-excavation in soft sediments • Water management • Promote good collecting practice • Discourage antisocial behaviour	• Asham Quarry* • Clee Hill Quarries* • Eartham Pit* • Gilbert's Pit and Riddlesdown Quarry • Horn Park Quarry • Lime Craig and Teinland Quarries* • Robin's Wood Hill Quarry and Weybourne Town Pit* • Swaddywell Pit, Peterborough • Webster's Claypit • Woodeaton Quarry • Wren's Nest (West Midlands) • Dryhill*
• Maintain natural coastal processes • Avoid developments in front of or on cliffs or foreshore • Discourage development on eroding coasts that may as a consequence require coastal protection • Vegetation management is usually only required where natural processes are inhibited • Practice holistic coastal management taking account of anticipated impacts of climate change • Record key features likely to be lost to erosion	• Chewton Bunny* • Church Cliff and East Cliff, Lyme Regis • Dimlington Cliff* • Easton Bavents • Fairlight Cove • Hengistbury Head* • Lee-on-the Solent*

Table 2.2: Continued

	Type of site	Site code	Main potential threats and conservation issues
Exposure or extensive sites	River and stream sections	EW	• River management • Bank stabilisation • Vegetation encroachment • Development • Tree planting and afforestation • Hydro-electric schemes • irresponsible collecting
	Inland outcrops	EO	• Maintaining access (in particular scientific) to geological features • Vegetation encroachment • Tree planting and afforestation • Development • Inappropriate recreational activities • Vandalism • Irresponsible specimen collecting
	Exposure underground mines and tunnels	EU	• Scientific access to geological features • Depletion of resource • Resource becomes finite after mine closure • Flooding after mine closure • Collapse after mine closure
	Extensive buried interest	EB	• Inappropriate agricultural practices • Tree planting and afforestation • Development • Quarrying • Inappropriate recreational activities • Changes to hydrological systems
	Road, rail and canal cuttings	ER	• Vegetation encroachment • Slumping of faces • Face stabilisation • Tree planting • Development • Road widening schemes • Re-grading of slopes • Securing access for scientific / conservation purposes on active roads and railway lines

Conservation Techniques	Case Studies (Sites marked * were documented in Prosser *et al*., 2006)
• Maintain natural processes • Avoid installation of engineering structures • Discourage developments on cliff tops • Vegetation management • Avoid tree planting and afforestation near geological features • Record key features likely to be lost to erosion	• Browgill and Stockdale Becks, Skelghyll Beck, Doe Lea and Betton Dingle* • Carboniferous Stratotypes • Onny River* • Studley Wood
• Vegetation management • Avoid tree planting and afforestation near geological features • Developments such as roads, paths and buildings should be sited away from geological features • Promote good recreational practice • Discourage anti-social behaviour • Promote good collecting practice	• Brimham Rocks • Mam Tor, Burrington Combe and Raw Head*
• Consultation with the mine operator to promote best conservation practice and gain ongoing access for scientific study and recording of temporary sections • Providing there are sufficient reserves of material, mining activities are generally beneficial for conservation • Develop sustainable pumping methods once mining has ceased • Develop stabilisation solutions after mine closure	• Florence Mine*
• Promote appropriate agricultural practice • Avoid tree planting and afforestation near buried geological features • Restrict development close to buried geological features • Restrict removal of the buried geological features • Promote good recreational practice • Maintain hydrological systems	• Bradford Kames • Fenland Network
• Removal of rock debris and slumped material • Avoid engineering solutions such as concreting or meshing which conceal or prevent access to the interest feature • Vegetation management • Avoid tree planting near geological features • Built developments should be located away from geological features • Include appropriately designed conservation sections on new road sections • Secure access agreements	• Brewin's Canal • Farley Dingle • Hornchurch Cutting • Hylton Castle Cutting, Sunderland • Roade Railway Cutting

Table 2.2: Continued

	Type of site	Site code	Main potential threats and conservation issues
Integrity sites	Static (fossil) geomorphological	IS	• Coastal management • Development • Offshore renewable energy schemes • Quarrying and dredging • Infilling of natural depressions • Erosion and weathering • Vegetation encroachment • Tree planting and afforestation • Inappropriate recreational activities • Irresponsible specimen collecting
	Active process geomorphological	IA	• Coastal management • River and land management schemes • Onshore and offshore development • Quarrying and dredging • Tree planting and afforestation • Slope stabilisation • Drainage • Inappropriate recreational activities
	Caves	IC	• Quarrying • Inappropriate agricultural practices • Changes in the water environment • Development • Irresponsible recreational activities • Irresponsible specimen collecting • Differing needs of different cave users • Fly tipping • Vandalism
	Karst	IK	• Quarrying • Inappropriate removal of rock • Infilling of natural depressions • Vegetation encroachment • Development

Conservation Techniques	Case Studies (Sites marked * were documented in Prosser *et al*., 2006)
• Restrict quarrying and dredging • Restrict development and engineering • Avoid dumping and infilling of natural depressions • Vegetation management • Avoid tree planting and afforestation • Promote good recreational practice • Promote good collecting practice	• Birling Gap • Bradford Kames • Brimham Rocks • Hubbard’s Hill • Rusthall Common* • The Wealden Sandstone sites • Wiveton Downs (Blakeney Esker)
• Maintain natural processes • Practice holistic coastal and river catchment management • Avoid tree planting and afforestation on or near active process sites • Restrict development on or near active process sites • Avoid quarrying and dredging on or near active process sites • Promote good recreational practice	• Ainsdale Sand Dunes* • Birling Gap • Church Cliff and East Cliff, Lyme Regis • North Dock Tufa • Pagham Harbour • River Dane (Cheshire) • River Feshie* • Slade Brook • Wooton Bassett*
• Avoid quarrying of cave systems • Promote good agricultural practice to restrict pollution • Avoid activities such as dumping of effluent which can affect groundwater quality • Maintain hydrological systems within the catchment of cave systems • Promote good caving practice through caving clubs • Access agreements through responsible caving clubs • Promote good collecting practice • Discourage antisocial behaviour	• Bagshaw Cavern* • Fairy Holes Cave • Pen Park Hole • Yorkshire Dales Caves and Karst
• Avoid quarrying of important karst features • Avoid removal of limestone pavement (usage of Limestone Pavement Orders) • Avoid dumping and infilling of natural depressions • Vegetation management • Avoid development on important karst features • Maintain hydrological systems	• Cheddar Gorge • Yorkshire Dales Caves and Karst

Table 2.2: Continued

	Type of site	Site code	Main potential threats and conservation issues
Finite sites	Finite mineral, fossil or other geological	FM	• Irresponsible specimen collecting • Quarrying and mining • Development • Vegetation encroachment • Tree planting and afforestation • Fly tipping • Inappropriate recreational activities • Vandalism
	Mine dumps	FD	• Irresponsible specimen collecting • Large-scale removal of spoil • Re-profiling and levelling • Reworking of spoil • Development • Vegetation encroachment • Tree planting and afforestation • Potentially conflicting heritage interests • Fly tipping
	Finite underground mines and tunnels	FU	• Flooding • Collapse of mine passages • Stabilisation by infilling of mines • Irresponsible specimen collecting • Fly-tipping • Vandalism
	Finite buried interest	FB	• Inappropriate agricultural practices • Vegetation encroachment • Tree planting • Development • Quarrying • Removal of material • Irresponsible specimen collecting • Inappropriate recreational activities

Conservation Techniques	Case Studies (Sites marked * were documented in Prosser *et al*., 2006)
• Promote good collecting practice • Avoid quarrying or mining of finite interest features • Avoid development near finite interest features • Vegetation management • Remove fly tipped rubbish and discourage further tipping • Discourage antisocial behaviour and inappropriate recreation	• Charnwood, Longmynd and Joint Mitnor Caves • Ebbor Gorge • Gipsy Lane Pit • Globe Pit • Hope's Nose • Birk Knowles* • Horne Park Quarry • Purfleet Chalk Pit • Skiddaw
• Promote good collecting practice • Restrict access where appropriate • Rescue collecting and removal of material to a safe area if dump threatened • Vegetation management • Avoid tree planting and afforestation near mine dumps • Integrated management with other heritage interests	• Clockhouse Brickworks* • Ecton Copper Mines • Skiddaw • Tynebottom Mine • Writhlington
• Development of sustainable engineering solutions • Restrict access where appropriate • Promote good collecting practice • Discourage antisocial behaviour	• Alderley Edge • Ecton Copper Mines • Seven Sister's Mine • Skiddaw
• Promote appropriate agricultural practice • Vegetation management • Avoid tree planting and afforestation near buried geological features • Avoid development near buried geological features • Avoid removal of the buried geological features by quarrying • Promote good collecting practice • Promote good recreational practice	• Abbey Wood • Globe Pit • Purfleet Pits • Purfleet Chalk Pit • Wadsley Fossil Forest*

2.4.2: Site safeguard and management of threats

The main threats and issues on geodiversity sites are:

Safeguard and management of threats – planning

- development, including coastal protection and general construction
- restoration, landfill and backfill of quarries
- quarrying in some circumstances
- tree planting

Safeguard and management of threats – management

- vegetation encroachment
- face instability
- irresponsible specimen collecting
- inappropriate recreational activities, and
- ignorance of the importance of geodiversity (with consequent neglect) and the need to conserve geodiversity features

Climate change can also be considered as a threat to geodiversity sites as it may accelerate erosion on certain sites, cause increased vegetation growth and has implications for future developments and the impacts these may

The sequence of Quaternary sediments resting on the raised wave-cut platform at Gerrans Bay SSSI, Cornwall. Here, rock revetments and concrete walls have been used to protect the cliff from erosion and failure due to wave action, with the consequence that the sediments are effectively inaccessible along this portion of the site. ©Natural England/Natalie Bennett

Highcliffe to Milton Cliffs SSSI, Dorset and Hampshire. This site contains a succession of fossiliferous Eocene marine and brackish sediments that are of international importance for their stratigraphical interests. As a consequence of a long history of interventions on this coast, much of the succession is no longer naturally exposed (left image), and heavily graded and drained stretches, lacking exposure extend along much of the site (right). ©Natural England/Colin Prosser

Websters Clay Pit, a denotified SSSI in Warwickshire contained a Late Carboniferous flora consisting of early gymnosperms. These horizons were well-exposed (left). Permission was granted to completely infill the pit, resulting in a green field lacking any exposure, and no way of accessing the buried faces (right). See case study in Chapter 4. ©Natural England/Colin Prosser

have on geosites. The potential impacts of climate change are discussed more fully in Prosser *et al.* 2010.

In the case of SSSIs, planning issues related to site safeguard and the management of threats are mainly addressed through the planning system and the statutory requirement on site owners or occupiers not to undertake any damaging activities. The emphasis is on prevention of damaging activities through the use of planning and conservation legislation. The current planning policy for England, the National Planning Policy Framework (NPPF) came into force in 2018 and states that planning policies and decisions should contribute to and enhance the natural and local environment by protecting and enhancing valued landscapes, sites of biodiversity or geological importance in a manner commensurate with their statutory status or identified quality in the development plan (para 170).

Coastal protection is one of the most serious threats to geosites in England and instances of this may increase with the impacts of climate change (Prosser *et al.* 2010). Coastal geosites form a very important part of England's geological resource and large sections of coastline are designated as SSSIs. Any development which conceals rock or sediment exposures can result in the effective loss of the geological interest. In addition, any development which prevents or slows natural erosion can have a damaging effect, as erosion is necessary to maintain fresh geological exposures. Reducing the rate of erosion usually results in rock exposures becoming obscured by vegetation and rock debris. Furthermore, coastal processes are complex and no section of coastline exists in isolation. This means that coastal protection in one area may have indirect effects on other parts of the coast. For example, cliff protection may starve other beaches of sediment, accelerating cliff retreat in those areas. Therefore, developments do not necessarily have to take place within the boundary of a site to cause damage and it is important to take a broad view in judging the likely impacts of coastal protection.

Landfill, driven by the demand for waste disposal sites, has been a serious threat to the conservation of geological features in many quarries in the past; however the move to greater recycling and converting waste

Warboys Brick Pit SSSI, Cambridgeshire, provided exposures of the Oxfordian, Weymouth Member of the Oxford Clay Formation, key to correlating this part of the Oxfordian. During the landfill operation investigations took place in order to identify any areas where the retention of exposure could be retained. ©Natural England/Dave Evans to energy has reduced this threat. Landfill, inappropriate restoration and other backfill can effectively destroy the scientific value of a site by permanently concealing the features of interest (see Webster's Claypit Case Study) (see also Prosser 2003).

Quarrying is generally a positive activity from a geological conservation perspective. Quarries often provide the only rock exposures in some areas, particularly in lowland Britain, and they typically provide much better exposure of geological features than comparable natural exposures. Quarrying, however, can be a serious threat to integrity or finite sites (Table 2.2), where the geodiversity interests need to be conserved as a whole or they are of finite extent. The principles for the conservation of the geological features should form part of an early approach to agreeing restoration.

Afforestation can be a serious threat to geological and, in particular, geomorphological features. Tree planting on SSSIs usually requires the landowner to seek formal consent from the statutory nature conservation body and can be damaging, depending on the nature of the proposal and features of interest.

All of the above threats are dealt with through the planning system or the SSSI consenting system. Early consultation is important in ensuring that planning submissions and decisions take full account of geoconservation. Early consultation may also be important in reducing the overall costs to developers, through properly scoping out the issues that need to be addressed.

Milford Quarry, part of Cannock Chase SSSI, Staffordshire. Whilst a consequence of natural colonisation, the effect on the visibility of the exposures of the Triassic conglomerates for which this part of the SSSI is designated, can have the same impact as tree planting; making observation of the features impossible from a distance. ©Natural England/ Mick Murphy

Occasionally, as at Clawthorpe Fell SSSI, Cumbria, quarrying may impact on the interest features. Here, the planning system in combination with the extraction industry have retained and conserved areas of limestone pavement. ©Natural England/Peter Wakeley

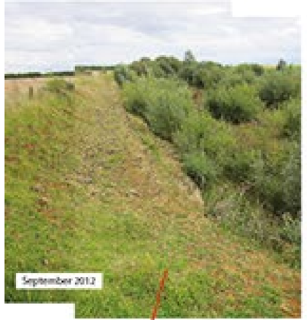
2.4.3: Site safeguard and site management

Management of geosites can include some or all of the following processes:

- production of site management plans and measurable conservation objectives
- regular monitoring of the condition of the interest features
- physical maintenance of features
- proactive engagement with site users, and
- production of interpretative materials

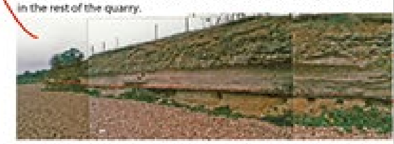
Partially flattened shells of the ammonite *Waehneroceras portlocki* (Wright, 1881), Blue Lias Formation, Hettangian, Early Jurassic, St Audries Bay, (Blue Anchor to Lilstock Coast SSSI) Somerset. ©Natural England/Dave Evans

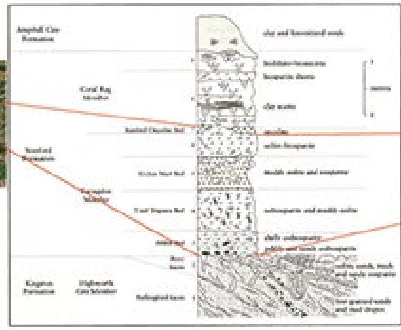
Management plans can take a variety of forms. For example, the Visual Managements Plan for Shellingford Crossroads SSSI, Oxfordshire, was prepared with the intention of giving a clear visual impression of the distribution of the interest features and the state of the site at the time of recording. This facilitated the clear specification of actions required to put the exposures in good condition. ©Natural England/Dave Evans

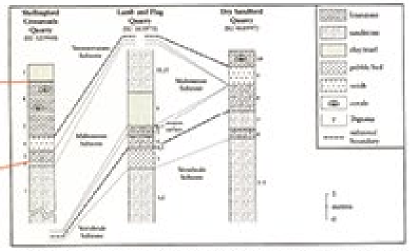


Panorama of northern side of SSSI during 2008. Water levels were particularly high at this time and reached the quarry face, creating pools up to 0.5 m deep at the bottom of the face.

Exposure toward western end of north face in 1993, several years prior to the reprofiling and partial infill. Rabbit erosion of the Highworth Grit Member of the Kingston Formation led to substantial undermining of the face. Subsequently, the face was reprofiled and benched, whilst infill was placed up to the base of the Stanford Formation (dashed red line), and the bund and island complex created in the rest of the quarry.







Relationship of Shellingford Crossroads to nearby SSSIs exposing Oxfordian succession.

Shellingford Crossroads SSSI, Oxfordshire

Northern Face

Area now heavily scrubbed over, predominantly by willow. This is impairing access to the face and has reduced tha visbility of the interset features both in close proximity to the face, and from the top of the bund. There is also talus agianst the face and a good deal of loose materail on the face.

Actions:

1. Within the area bounded by the blue line, all scrub needs to be cleared, and the potential for regrowth addressed through the treatment of stumps.

2. The area may require further treatment should any regrowth be detected.

3. The whole area bounded by the the blue line may need to #be cleared by brush cutting at intervals of about five years.

4. Cuttings originating from vegetation clearance should be burnt onsite or disposed of offsite in order to minimise tha quantity of organic material remaining in this area.

5. Where the exposures have become obscured by talus, this should be pulled back.

6. Loose material on the face should be removed, but not to the extent where its removal involves the loosening of rock embedded in the face

Remaining exposure on southern side of site

This exposure lies outside the SSSI boundary, but shows the lowest portion of the succession (base of the Stanford Formation and top of the Kingston Formation, which can no longer be seen within the SSSI. Ideally this area should form and additional and separate unit of the SSSI. The soft sands of the Highworth Grit Member of the Kingston Formation have been extensively burrowed by rabbits and foxes, leading to the development of overhangs in the overlying Kingston Formation, risking future collaps of the face. In order to maintain the interest features in this area:

Actions:

1. The overhanging rock may need to be removed.

2. Scrub and small trees within the boundary should be removed and the stumps treated.

3. Control of further burrowing needs to be introduced. This might involve the instalation of rabbit fencing around the perimeter with gated access to the floor.

4. The lack of grazing as a result of rabbit exclusion would require that the area within the boundary might need to be brushcut on a regular 2-3 year cycle.

5. Hard fences at the crest would need moving/reinstatng after the removal of the overhang.

2.4.3.1: Site management plans and conservation objectives

Site management plans are important as they can clearly define what actions are required to manage and maintain geological sites (Prosser *et al.* 2018). They should be specific, identifying particular interest features and measurable objectives for the features. They should clearly define how and when objectives are to be met and who is responsible for meeting these objectives. Detailed conservation objectives provide a simple framework for condition assessment.

Monitoring the exposures of Toarcian (late Lower Jurassic) limestones at Coaley Wood SSSI, Gloucestershire. ©Natural England/Dave Evans

The following should be considered within the development of a site management plan:

- A detailed and accessible description of the important geological interest features
- A detailed map of the site showing the location of the interest features
- Fixed-point photography of the site and interest features (which is important for monitoring)
- Consultation with site owner and other stakeholders
- A list of potential threats and management issues, including risk assessments
- Details of other conservation interests, such as biological or archaeological features
- Site-specific measurable conservation objectives for each interest feature
- Responsibilities for achieving and maintaining the conservation objectives
- Details of how the site is used and its potential for education
- Details of management processes, including timescales for initial remedial works and frequency of subsequent maintenance works
- The frequency of monitoring required
- The resources needed to deliver the management plan, and
- When the management plan should be reviewed

Large and rapidly changing working sites such as Swinden Quarry SSSI, North Yorkshire may provide access to a complex set of features. In this case a series of Lower Carboniferous reef knolls and their flank facies are exposed. Regular recording of these exposures provides important information for the interpretation of these structures and may help to inform the restoration plans for such sites. ©Natural England/Mick Murphy

Foss Cross Quarry SSSI , Gloucestershire is landfilled. It contains a retained conservation face that is actively managed in order to maintain clear exposures. This image, combined with others of the site can act as a base-line by which these exposures of the Middle Jurassic, White Limestone Formation can be managed and maintained into the future. ©Natural England/ Dave Evans

In Natural England, site-specific conservation objectives are produced by tailoring generic favourable condition tables (Annex C) to individual sites. The generic tables are based on the ESCC (Section 2.4.1) and can be easily modified into site-specific documents. It is important to set realistic objectives. For example, in a disused quarry, dense vegetation may be concealing the features of interest. While the ideal from a geological perspective may be to maintain total exposure along the entire site, the cost of clearing and maintaining the whole face permanently free of scrub may be prohibitive and more realistic objectives could be to maintain a small section or sections of face, or in the case of poorly consolidated sediments, to maintain a light covering of vegetation. This approach may be sufficient to maintain the site in an acceptable condition.

The production of conservation objectives has the potential to remove much of the subjectivity associated with geological site condition assessment. For example, if measurable targets have been set for the length of section that needs to be maintained free of scrub for a site to be in favourable condition, it is a relatively straightforward process to check if these targets are being met.

Site management plans should ideally include objectives for any other conservation interests on the site, such as wildlife and archaeology. It is important to take an inclusive view and integrate the requirements of all of the interest features (for example Pitstone Quarry SSSI, Buckinghamshire (Brown 2013).

On sites where there is public access, the management of visitors and associated health and safety requirements should be incorporated into the management plan. A visitor management strategy may also help to avoid damage to the geological interest. Where appropriate, a strategy for managing specimen collecting should be part of the management plan, see Section 2.4.3.5 for details on responsible collecting.

2.4.3.2: Site monitoring

Site monitoring is a vital part of the process of geoconservation as it is essential to regularly check that the interest features are not degrading and that there are no damaging activities occurring. Regular monitoring is necessary to determine whether conservation objectives are being met and to identify what management actions may be required.

As with the production of conservation objectives, the ESCC (Section 2.4.1) is used as the basis for identifying generic threats and issues associated with each site type. Generic forms can be devised for the different site types. As long as the geology has already been documented in the conservation objectives or a site management plan, it is often a straightforward exercise to check on the condition of a geosite. Natural England's procedure for site monitoring is described more fully in Annex A.

Photographic monitoring is strongly recommended for keeping track of changes to sites over time. Photographs taken at regular intervals from a fixed point provide a visual record of changes, which is much

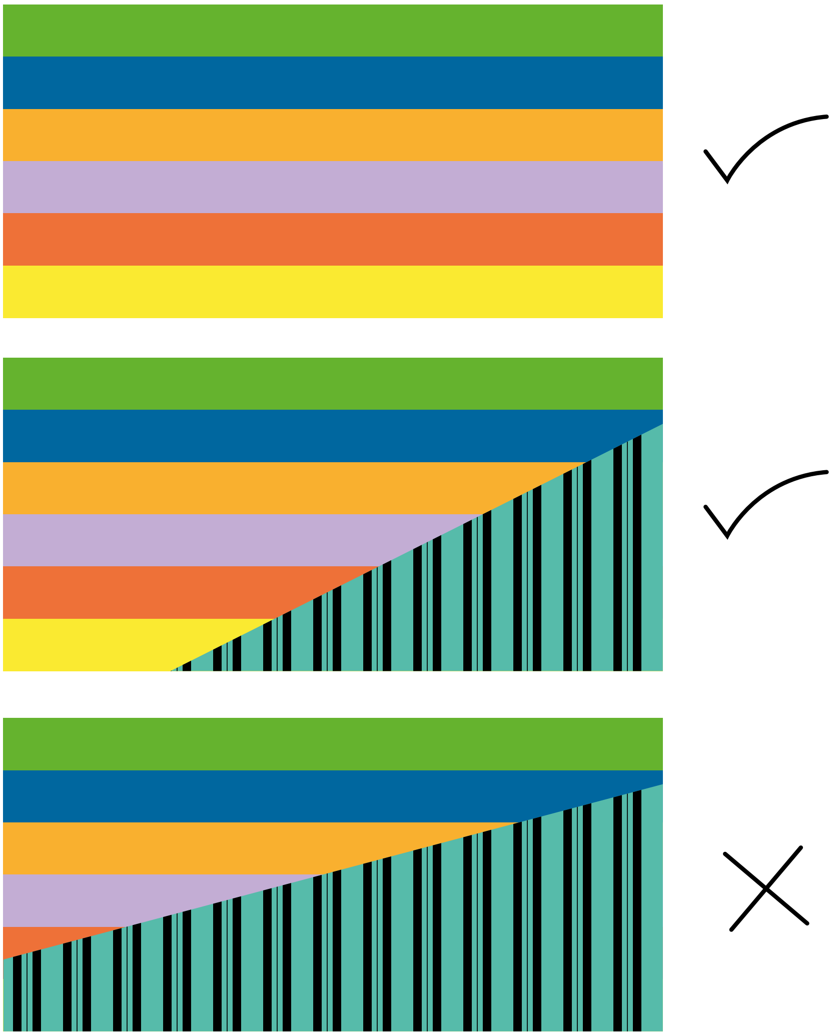
Where there has been a long history of quarrying and landfill. The location and condition of the interest features may be poorly understood. Here at Bakers Hole SSSI and Scheduled Ancient Monument (SAM) in Kent, development has buried a range of features providing information on the Quaternary evolution of a tributary of the Thames. Detailed surveys have been necessary in order to locate and assess the condition of these features. ©Natural England/Eleanor Brown

more objective than a written record in demonstrating actual changes in vegetation (Larwood 2002; Rowarth & Larwood 2004), scree cover or site use. With the advent of high quality, low cost digital cameras, photographic records can be readily stored in electronic form. Digital images are most effectively stored as part of searchable electronic databases, together with other relevant site information. It is important that the fixed point is clearly described and precisely located so that the process can be repeated at regular intervals. It is also important to take photographs at a similar time of year and day so that vegetation and light conditions are comparable.

Other imagery techniques with an application to geosite monitoring include photogrammetry which can provide a high resolution (and 3D) image of specific features, and Unmanned Aerial Vehicle (UAV) which

Excavation of the disused Welton-Le-Wold Gravel Pits SSSI, Welton, Lincolnshire has resulted in the re-exposure of a succession of tills and gravels that have facilitated a reinterpretation of the late Quaternary history of glaciation in Lincolnshire. ©John Arum reproduced with permission

Figure 2.2a: Exposure of features of interest - horizontal



(A) Full succession exposed.

(B) Full succession remains exposed.

(C) Lower part of the succession is lost.

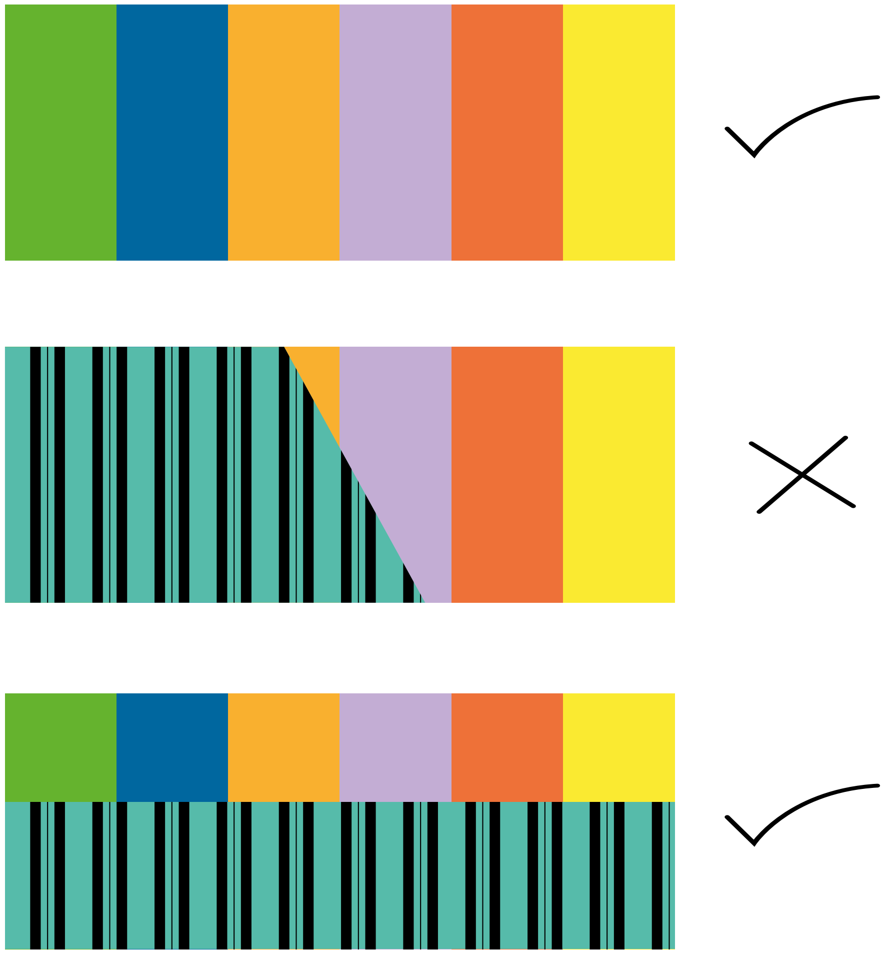
Figure 2.2a shows horizontal bedding, with different rock layers resting on one another. Here it is important that the full height of the face is exposed, so all the different rock layers and the relationships between them can be seen and studied. However, it is not necessary to keep the full length of the face exposed, as the same rock layers and relationships are present along the full length of the face.

can provide an image of a wide area, and is particularly useful where access is difficult.

2.4.3.3: Physical maintenance of sites

Ensuring that the features of interest are in good condition and can be readily studied by site users is an important part of geological site management. Site maintenance can include vegetation control, scree clearance, face scaling, re-excavation, rubbish removal, fencing and access management.

Figure 2.2b: Exposure of features of interest - vertical



(A) Fully exposed.

(B) Infill or batter obscures part of the succession.

(C) Infill or batter to half the height of the exposure. The succession remains fully exposed.

Figure 2.2b shows vertical bedding (where earth movements have rotated the bedding away from horizontal). Here it is important that the whole length of the face is exposed, so all the different rock layers and the relationships between them can be seen and studied. However, it is not necessary to keep the full height of the face exposed, as the same rock layers and their relationships are seen throughout the entire height of the face. This would also apply to inclined or dipping beds.

In order to determine the location and nature of the site management needed, it is important to understand the nature of the geological interest features and how they are distributed within the site. These four diagrams (Figs 2.2a-d) consider some simple generic principles for maintaining the geodiversity interest. In practice many sites have more than one type of geodiversity interest. With such complex relationships a combination of approaches may be required.

Figure 2.2c: Exposure of features of interest - lateral

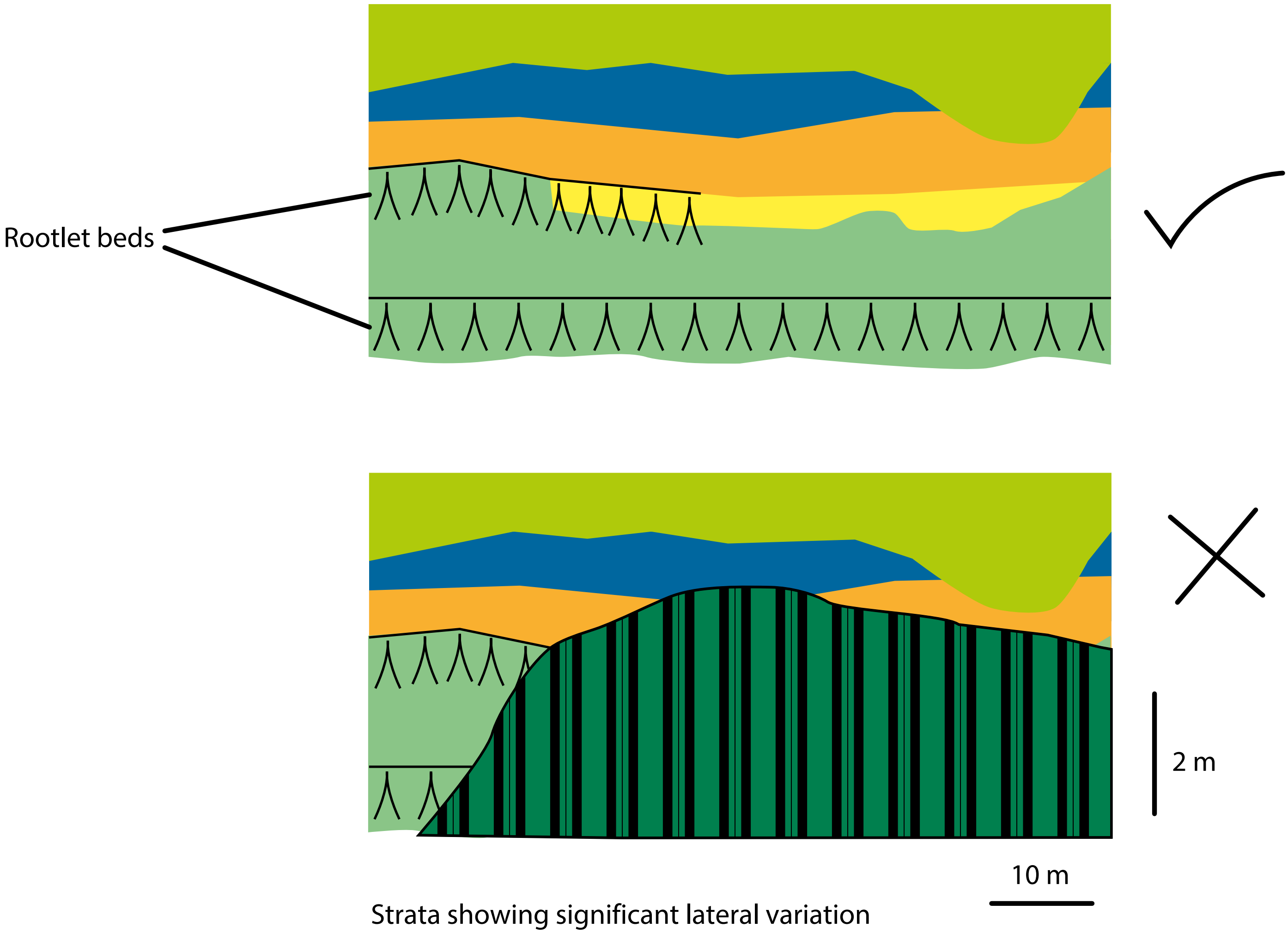


Figure 2.2c shows a site with significant lateral variation in the bedding. Here it is important to see all the different rock layers and the relationships between them. Covering any part of the face would result in the loss of important relationships and impede understanding of the site.

Figure 2.2d: Strata showing features in three dimensions

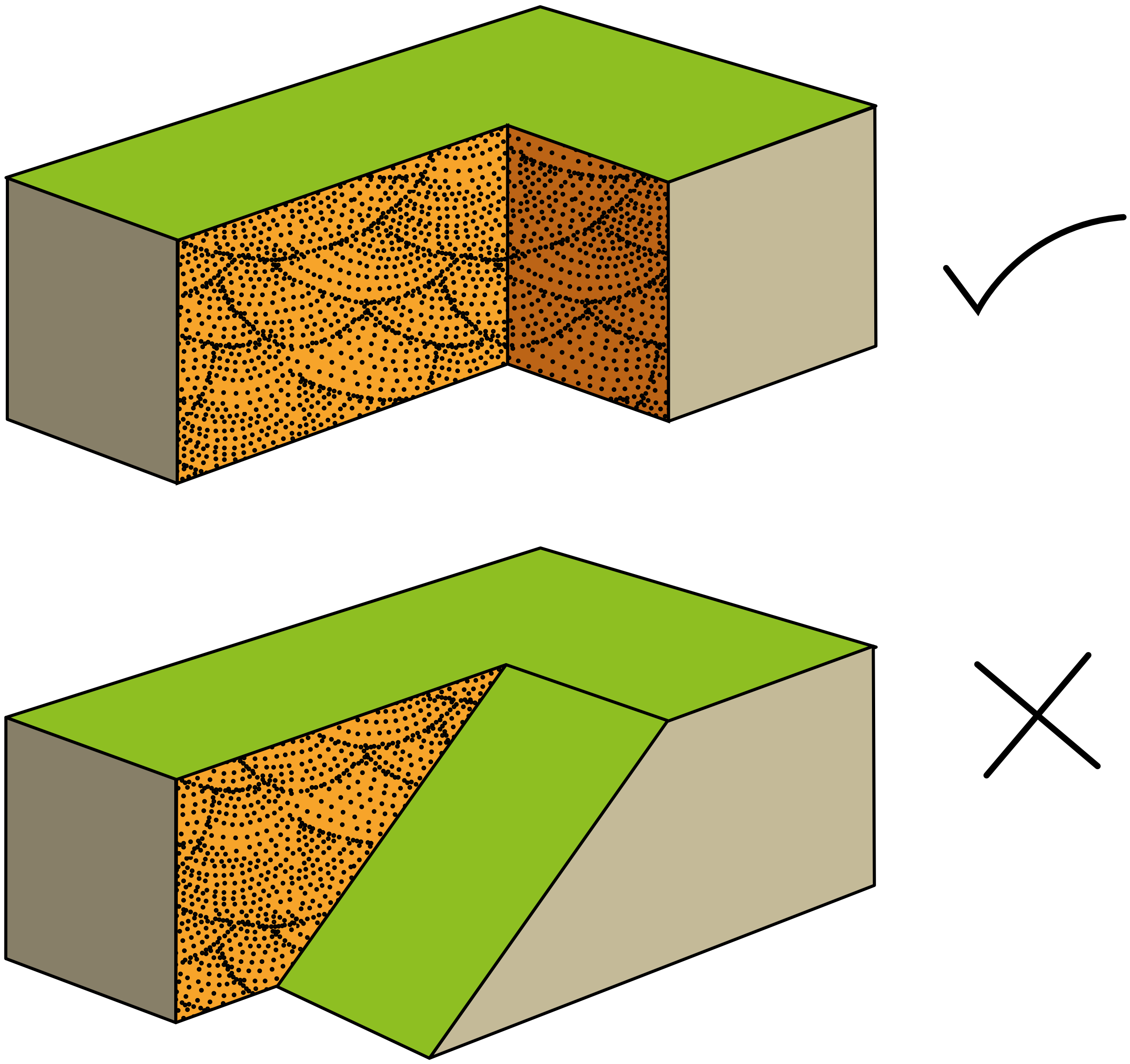


Figure 2.2d shows a site where it is important to maintain at least two adjoining faces that are more-or-less upright and at a right angle to each other, as in order to understand the interest features (for example a fossil sand dune or river channel) they need to be interpreted in 3 dimensions.

2.4.3.4: Funding to manage sites

In England there are currently two main funding schemes to support the management of geodiversity SSSIs.

1. Countryside Stewardship is a scheme which will helps Natural England deliver environmental outcomes for biodiversity, protected sites and priority habitats. It is a voluntary scheme that rewards land managers for improving the environment. Land managers can apply for 'agreements' (contracts) of varying length specifying activities that will benefit the environment on their land. Agreement offers are subject to eligibility criteria and a competitive application process. Geodiversity sites are included within this scheme, however, the geosites must be part of a wider scheme application to be eligible; in practice many geosites do not receive funding through this scheme. A new Environmental Land Management Scheme (ELMS), to replace Countryside Stewardship, is currently being designed. It is hoped this scheme will include specific site management options for geosites and will encourage greater uptake from land managers. It is anticipated that most geodiversity SSSIs will be eligible for funding under the new scheme.

2. The Conservation and Enhancement Scheme (CES) is a Natural England-funded initiative aimed at enhancing SSSIs in England where Government-funded Countryside Stewardship cannot be used for management works. This includes sites that are important for their open-water, sub-littoral habitats or geology. Each agreement includes a management plan and can last up to five years, so any initial management works can be maintained. Due to funding rules, the initial agreement has to be between the landowner and Natural England, but local groups can and do get involved in the management works. Up to 2017, 65 CES agreements have been set up for geodiversity SSSIs. Due to lack to funding, no new CES agreements for geodiversity SSSIs were created in 2018 or 2019. It is anticipated CES will be replaced by this new Environmental Land Management Scheme.

Funding for site management is also available from a range of grant givers, for example, the broad-based National Lottery Heritage Fund or more specific funds such as the Geologists' Association Curry Fund or the Quaternary Research Association Geoconservation Award.

Mini-digger creating a trench at Tideswell Dale, in The Wye Valley SSSI, Derbyshire. The trench exposed the previously hidden lower contact of the Tideswell Dale Sill with the Carboniferous Limestone, increasing understanding of the nature of this igneous intrusion. ©Natural England/Mick Murphy

Hebridean sheep grazing at Swaddywell Pit, a LGS near Peterborough, Cambridgeshire. Grazing can be a very effective method for vegetation control, particularly in inhibiting the development of scrub. ©Natural England/ Dave Evans

2.4.3.5: Managing recreation and access

Specimen collecting and recreational damage, inadvertent or otherwise, can be a serious problem on some sites. While legislation provides protection against third-party activities, it is generally more effective to prevent damage before enforcement is required. As long as specimen collecting is undertaken in a responsible and sustainable manner, it should not present a serious conservation problem. It is important, however, that management of collecting reflects the available resource and associated collecting pressure. In particular, where the resource is finite, careful management of collecting is required. A range of site-based mechanisms can be used to manage collecting, including signage, fencing, managed access and permit systems, and, in extreme circumstances, the construction of secure covers, the burial, or removal of a resource to a safer locality.

Fences, defined paths and steps at Kirklington Quarry, Oxfordshire (SSSI and LGS) guide visitors around the site, reducing the impact of footfall on exposures, but allowing sufficient access for general observation and close inspection of the Middle Jurassic sediments exposed in the quarry. ©Natural England/Dave Evans

One of the most effective methods of preventing irresponsible collecting is to educate people about the value of and need to conserve the geological resource. This will often lead to collectors developing a sense of responsibility towards the resource from which they collect. This involves devising good practice collecting policies in collaboration with collecting groups and societies, who can then communicate agreed policies with their members (Bassett *et al.* 2001, Townley 2003 and National Trust 2007). Natural England has worked with various collecting groups and landowners to develop mutually acceptable collecting guidance. This involves promoting the concept of responsible collecting and recognising the important role that fossil and mineral collectors can play in advancing the sciences of palaeontology and mineralogy. Peer pressure to conform to acceptable good practice collecting policies can often be much more effective than attempting to apply more draconian policies which may be practically unenforceable.

Searching for sharks teeth on the lower foreshore of Bracklesham Bay SSSI, Sussex. Fossiliferous sediments of the Eocene Bracklesham Group (inset), are scoured during storms, releasing a prolific assemblage of fish teeth. Other recreational uses of the site (wind-surfing and para-gliding) have necessitated the resolution of conflicts caused by the zoning of the foreshore and the exclusion of collectors from some areas. ©Natural England/ Dave Evans

West Harnham Chalk Pit SSSI, Salisbury, Wiltshire, provides exposures of a Chalk succession that is best studied in the quarry faces or in fallen blocks. This means that other uses of the site, such as acrobatics on bicycles are not necessarily in conflict with the objectives of conserving the Chalk stratigraphy here. ©Natural England/Mick Murphy

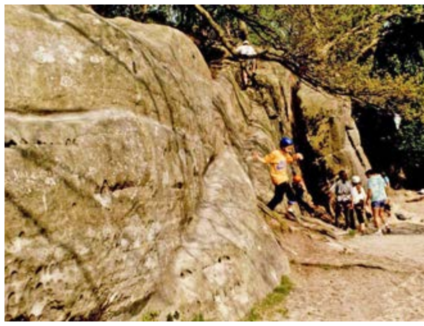
Natural England has produced separate guidance on managing specimen collecting (Natural England, 2012a) and the principles of responsible collecting (Natural England, 2012b), which are summarised here:

- Permission to enter private land and collect geological specimens must always be obtained
- A clear agreement should be made with the landowner over the future of any specimens collected
- In general collect only a few representative specimens from fallen or loose material
- Scientific study may require collection of *in situ* specimens; any such collecting should be carefully planned and focus on scientific needs
- Wherever possible avoid sampling the most visible exposures or those critical to interpreting the site
- Always make a precise record of the locality at which specimens are found and, if collected *in situ*, record relevant horizon and associated details, including linking specimens to information such as site name, grid reference and, if possible, photographs

In most cases, collecting by hand from loose material is sufficient. Hand tools, where allowed, should only be used when essential and power tools only used in exceptional circumstances. Any form of excavation is likely to require permission before it is undertaken.

Always avoid disturbance to wildlife, be aware of other people and ensure that the site is left in a tidy and safe condition for those who follow. Ensure that all records can be directly linked to any specimens collected. Scientifically important specimens should eventually be placed in a suitably managed collection to ensure they remain available for further study.

Outdoor activities such as walking, mountain biking, off-road driving, climbing and caving can cause inadvertent damage to geological and geomorphological sites. This can be through overuse causing erosion and degradation. In most circumstances, however, these activities can be sensitively and sustainably managed without damage to geological interests.



Rock climbing on Stone Hill Rocks SSSI, Sussex. Although the interest features (sedimentary structures within the sandstones) are relatively robust, ropeware and footware may cause erosion and lead to damage in the long-term if not managed. ©Natural England/Richard Cottle

Walking, mountain biking and off-road driving can cause localised erosion, compaction and visual impact. This can be problematic when geological features are limited in extent (such as a mineral dump or spoil heap), unconsolidated, soft, or poorly cemented (such as sands, gravels and clays), or part of a landscape where interpreting geomorphology is critical, or natural processes should remain unimpeded. Working with relevant user groups and local communities is important, alongside route and path management that can include re-directing people and paths where necessary and feasible, undertaking careful restoration and management of routes to reduce erosion, and use of signage.

Climbing can cause damage particularly on softer rocks. Regularly used climbs can cause wear from rope and shoe abrasion, and cleaning of rock surfaces and climbing holds. Surface geological features and associated species such as lichens and bryophytes can be at risk. Working with climbing groups and establishing good climbing codes of practice will limit potential damage. For example, the Southern Sandstone Code of Practice has established a set of principles for the soft Cretaceous Wealden sandstone crags of southeast England. They have both important surface weathering features and rare bryophyte and fern communities which are particularly vulnerable to the high levels of climbing they receive.

Marine Permian carbonates exposed at Quarry Moor SSSI, Ripon, North Yorkshire lie within a Local Nature Reserve. The exposures themselves have been fenced off at a distance where the features are easily seen, and this aspect of the site has been integrated into the other interests and activities that take place on the LNR. ©Natural England/ Mick Murphy

Toad Rock, Rusthall Common SSSI, Tunbridge Wells, Kent. Designated as an example of a classic landform formed by wind erosion under periglacial conditions, this site, and others like it are particularly sensitive to the effects of climbing. These are caused by ropes and feet wearing though the thin skin of cemented sandstone into the soft sandstone beneath; greatly accelerating erosion. The perimeter fence affords the rock a degree of protection from graffiti (both sprayed and engraved), as well as from climbing. ©Natural England/Dave Evans

The core principles are:

- Use a non-stretch belay rope and sling
- Make sure the karabiner hangs over the edge of the crag
- Make sure moving ropes do not come into contact with the rock
- Clean your shoes before starting each climb
- Walk off when you have finished a climb, do not lower off or abseil
- Keep chalk use to a minimum

A similar approach has been taken for caving working with caving groups to establish good conservation practice. Features such as cave pools, speleothems and cave sediments can be particularly vulnerable to disturbance, breakage, excavation and compaction. Natural England has worked with both national and local caving groups developing and promoting codes of good practice such as the Minimal Impact Caving Guidelines (produced by the British Caving Association, British Cave Research Association, and Natural England) sets out principles for cave visits and exploration and provides advice on safe caving and careful route selection and how to recognise and avoid damage to sensitive cave features and wildlife.

The core principles, as outlined by the Derbyshire Caving Association, are:

- Cave with care and thought for the environment
- Disturb nothing whether living or geological

- Avoid touching formations
- Keep to marked routes and never cross conservation tapes.
- Take nothing but photographs
- Do not pollute the cave, leave nothing behind

New cave and extension exploration is also covered emphasising the importance of a cautious approach and the need to keep good records, take photographs, and work closely with the relevant statutory bodies and research groups. Many local caving groups also take direct responsibility for managing caves and implementing cave conservation plans in their local areas. For example the Bagshawe Cavern Conservation Plan (Bradwell Dale and Bagshawe Cavern SSSI, Derbyshire) compiled by the Eldon Pothole Club. This conservation plan grades sensitivity and identifies restricted areas, providing advice and guidance for different visiting groups, as well as an overview of current conservation and cave research activities.

Further information:

- Eldon Pothole Club and Bagshawe Cavern Conservation Plan
- British Mountaineering Council (BMC) Southern Sandstone Code of Practice
- BCA, BCRA, NE Minimal impact caving guidelines

Monitoring cave features in a Cumbrian cave system ©British Cave Research Association/Dave Checkley reproduced with permission

2.4.3.6: Site interpretation

Interpretation is an area of expertise in its own right. Here is not the place to describe how to produce effective interpretation for geosites, instead the importance of interpretation for geoconservation is summarised, and some general interpretive planning considerations are outlined. Some selected examples of good practice are provided, and sources of further guidance are indicated.

Interpretation board at Creswell Crags SSSI and Scheduled Monument (SM), Derbyshire. This incorporates large, memorable images with relatively little text. While located on an interpretation trail it is positioned so that it does not intrude on the view. ©Natural England/Anna Wetherell

Why is geological interpretation important?

Geology is inherently difficult to explain, the language is impenetrable, the timescales are vast and the processes are complex. Often it is not even visible! However, the history of our planet is fascinating, exciting, dynamic and occasionally explosive! Our natural resources come from rocks and the habitats and species that grow on them. Geodiversity is a fundamental part of nature, which sustains life. It's also a vital subject for conservation and sustainable development as it tells us how the Earth works and changes over time. These factors present both significant challenges and substantial opportunities for geological interpretation. Freeman Tilden (US National Parks Service) succinctly said that

> 'through interpretation, understanding, through understanding, appreciation, through appreciation protection' (Tilden, 1977).

Stewart & Nield (2013) state that sustaining guardianship over the longer term needs a broader and deeper public consciousness about both geodiversity and geoconservation. Interpretation is vital for successful geoconservation. It reveals meaning and can help us understand and appreciate our natural world and the need to conserve it.

Interpretative Planning

Delivery of successful interpretation is all in the planning. There are numerous texts, websites, professional associations, training courses and even degree courses that, depending on the time available, will get you up to speed on how to plan your interpretive project. Some are listed at the end of this section. For large projects with funding, it will probably be worthwhile to engage an interpretive specialist or consultancy. However, for planning your own project, the key points are:

- To understand your resource. What is it that you want to interpret? What is visible on the site? An audit or inventory of geological

Interpretation at Penlee Quarry SSSI, near Penzance, Cornwall. A variety of rock types and examples of mineralisation in the quarry have been incorporated into a compass and sundial above the entrance to the quarry. ©Natural England/Hannah Townley

features, outcrops, fossils, landforms etc. is needed, along with any connections to other areas of interest e.g. industrial archaeology, building stone, ancient human activity, transport, wildlife, protected landscapes etc.

- To understand your audience e.g. local visitors, school groups, university groups, international visitors etc.

- To decide on the theme for your interpretation. This is the one thing, the story or take home message that you want your audience to remember, expressed as a single sentence. For larger sites, an overarching theme is appropriate, with sub themes for individual stops on a trail or signboards. For example the overarching theme for the Jurassic Coast World Heritage Site is 'A Walk Through Time'.

- To decide what the educational, emotional and behavioural objectives are, so in other words what you want visitors to know, feel and do. For example to understand the rocks are fragile because they are made of soft sandstone, to feel a connection with the wild beauty of the site and to take action to protect it by not climbing on the rocks.

- To decide on appropriate media for your interpretation given the site and its circumstances. For example, have you got a visitors centre? If there are lots of things to see, is a self-guided trail with a leaflet, audio guide or posts with QR codes to download interpretation on phones appropriate? Is the site very exposed or open 24 hours a day without site managers present, and therefore is fixed interpretation (e.g. panels, signs) likely to get vandalised or need replacing frequently due to exposure to the elements? Are there any constraints e.g. nature conservation designations, access management restrictions, the need to spread visitors out to avoid damaging honeypot sites, and a need to avoid signage clutter spoiling the aesthetics of your site? Interpretation doesn't have to just be through traditional media such as panels, other forms of interpretation such as art e.g. sculpture trails, temporary exhibitions, photography etc. can also be very successful. In places where the audience is very diverse, it may be appropriate to have different layers of interpretation e.g. an interpretation panel next to the rock exposure with a QR code linking to more in depth interpretation online for students and amateur geologists. On site interpretation e.g. trails, panels, is best where the geology you are interpreting is visible. Finally, live and interactive interpretation through talks, guided walks, hands on experiences such as fossil hunting (in appropriate places where the resource is sustainable) and the careful use of technology and hands on exhibits are often the best forms of interpretation, however they also take the most effort.

Hand axe sculpture at the entrance to Swanscombe SSSI and NNR, Kent. The Pleistocene sediments at Swanscombe are largely buried in order to protect the remaining resource. Prominent sculptures such as this are memorable and may remind and emphasise to site users the value of the place. ©Natural England/Eleanor Brown

Harehope Quarry, Frosterly, Co. Durham. Cut block of Carboniferous Frosterly Marble set next to quarry trail and stream, allowing the cut surface to be wetted, to enhance contrast so that details of the coral skeletons are visible. ©Natural England/Jonathan Larwood

- To design engaging interpretation using stories that capture the imagination. The interpretation mantra ‘provoke, relate and reveal’ (Veverka, 1994) can help guide. This is because interpretation is distinct from education (where students are expected to study to pass a test) as the audience can choose to participate or not. Interpretation is sometimes described as edu-tainment.

- To plan implementation. This will involve costing and designing your interpretation and any additional infrastructure it requires e.g. a new path to access a feature, additional electric lighting in a visitor centre, a projector and some fossil storage boxes for giving a talk. It’s also important to add in how the interpretation will be advertised to the intended audience, and consider any other issues including health and safety.

- To review and monitor your interpretation to check it is delivering as expected. This is crucial for planning replacements and upgrades as interpretation (particularly physical installations such as panels) have a lifespan, or indeed planning the next interpretive project (e.g. the review of visitor centres in Scotland by Strathspey Surveys, 2006).

Giant trilobite (about 1.5 m long) carved out a block of wood as part of a community sculpture project involving local residents surrounding Wren’s Nest NNR, Dudley, West Midlands. The sculpture has been on the NNR for ten years. ©Natural England/Jonathan Larwood

Case studies and examples

There are many examples of good practice around the country and around the world, where interpretation has been designed carefully for the location, the audience, the resources available and the conservation issues at hand. Some interpretive projects are very large and funded by large grants e.g. the sculptures and interpretation panels at the Wren’s Nest National Nature Reserve (NNR) in Dudley, delivered by the Ripples Through Time (theme) project funded by the Heritage Lottery Fund. The iconic sculpture of a hand axe at the entrance to the Swanscombe NNR, the site of the second oldest human fossils in Britain, is also an example of using art for interpretation.

An example of layering can be found at Pitstone Quarry SSSI, Oxfordshire, part of the [Berkshire, Buckinghamshire and Oxfordshire Wildlife Trust](). As well as on site interpretation panels, BBOWT have a visitor centre which contains more detailed information about the site including photographs and fossils. There are also trails around the site for children and static exhibitions, as well as various events throughout the year for schools and other audiences. A ‘geological story’ of the nature after minerals site has also been developed for College Lake, which has a more detailed deep dive into the geology aimed at interested people, amateur and professional geologists and educational groups. This was produced to inform other interpretive projects at the site but is being developed as an interpretive product in its own right.

Newly created section and interpretation board at Pitstone Quarry form part of an integrated scheme covering a variety of interests using a range of different media. ©Natural England/ Eleanor Brown

Knockan Crag in the Northwest Highlands UNESCO Global Geopark, is a very good example of a nodes and networks approach to geological interpretation, with a central visitors centre accompanied by a trail, complete with a number of satellite sites with interpretation panels linked by a car (drive yourself) trail. Scottish Natural Heritage (now NatureScot) have also reviewed the effectiveness of their interpretation at Knockan (and other sites) and the resulting publication listed several recommendations for improvement. These can be factored in when designing new interpretation elsewhere or upgrading/replacing the interpretation at Knockan when it reaches the end of its life.

Sculpture on Knockan Crag NNR, Western Highlands. The sculpture comprises one of series set around the Knockan Crag Trial, and these form one element of the interpretation strategy on the site, and in the wider context of the Northwest Highlands UNESCO Global Geopark. ©Natural England/Colin Prosser

The possibilities for geological interpretation are infinite, and this section can only provide broad guidance and maybe stimulate some thought on best practice, resources, and getting projects started. Ultimately, geological interpretation needs people to retain feelings rather than facts, as these will last much longer (Stewart & Nield, 2013).

Further information and resources:

- Association for Heritage Interpretation
- Interpret Scotland
- A Sense of Place, An interpretive planning handbook

Sculpture of a mammoth created in wood and live willow and forming part of the interpretation on Creswell Crags SSSI and SM. ©Natural England/Anna Wetherell

Middle Jurassic ammonites, preserved in the Peterborough Member of the Oxford Clay Formation near Whittlesey, Cambridgeshire.

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