Geoconservation: principles and practice

Part 3 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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Citation

This report should be cited as:
EVANS, D., BROWN, E., LARWOOD, J., PROSSER, C., SILVA, B., TOWNLEY, H and WETHERELL, A. 2023. Geoconservation: principles and practice. Natural England General Publication NE802, Natural England.

This publication is an update based on:
Geological conservation: a guide to good practice
By: Colin Prosser, Michael Murphy and Jonathan Larwood (2006). English Nature. 145 pp.

Due to file size, this publication is also available to download in three parts - the reference list, appendices and acknowledgments are all present in part 3. Please note the different Natural England Publication Code and ISBN.

This is PART 3 of 3:
ISBN 978-1-78367-377-3
Natural England General Publication NE789

Front cover images
Clockwise from top right:

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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Chapter 4: Case Studies

The following case studies provide examples of a variety of approaches to management and management techniques that have been applied to sites that belong to different classes within the Earth Science Conservation Classification. The case studies include updates of studies originally reported in “Geological Conservation a guide to good practice” (Prosser *et al.* 2006), as well as relatively new examples. Although in most cases, outcomes are positive, it should not to be assumed that this will be the outcome in every case, and examples are included, where despite the best efforts of all partners, the conservation of the site remains problematic.

Before, during and afterwards: clearance of Marsh Wood Quarry SSSI, Shropshire. This overgrown and long-disused quarry exposing Late Ordovician sediments has been cleared, re-exposing the full succession for which it was designated. The need for regular management is demonstrated (bottom) by the ground flora and accumulation of fallen leaves that are gaining a foothold only eight months after the works were carried out. Middle image: ©Jason Ball, Geckoella Ltd. Bottom and top image: ©Natural England/ Dave Evans.

4.1: Frogden Quarry SSSI
An active quarry (EA) in Dorset

Conservation issues

- **Conserving geological interest as part of a small, active, building stone quarry**
- **Facilitating on-going research in an active quarry**
- **Retaining geological features as part of long-term restoration**

4.1.1: Site description

First recorded in the late 19th century, Frogden Quarry, near Oborne in Dorset, provides expanded sections through the Middle Jurassic Lower–Upper Bajocian sequence of the Inferior Oolite Formation (which are elsewhere incomplete or condensed). Having been disused for some time, in 2005 permission was granted for the re-opening of Frogden Quarry for the extraction of the local Sherborne Building Stone in an area extending beyond the existing SSSI. Frogden has become a rare active quarry in Buckman's area of classic research and as a consequence has continued to yield important new material enabling a detailed reappraisal of this part of the Inferior Oolite succession.

4.1.2: Challenge and actions taken

With the opportunities that would arise from the renewed exposures and collecting resources, it was important to establish suitable planning conditions to enable on-going research and the retention of accessible sections as part of the final quarry restoration.

The site's statutory importance as a SSSI and, in particular, the co-operative and collaborative relationship between the site owner and research community enabled the establishment of conditions facilitating research and educational use during the working life of the quarry as well as the retention of long-term conservation faces. In summary, planning conditions require:

1. Restoration to include additional exposures at the western edge of the quarry (scheme to be submitted and agreed prior to the last stage of overburden removal).

2. Scheme for temporary section recording and sampling to be agreed specifically to include:

   a) Procedure for recording and controlling the collection of fossils directly from the quarry face.

   b) Procedure for limiting personnel or parties authorised to collect fossils direct from the face

Frogden Quarry SSSI, Dorset in 2011. Showing largely overgrown faces and floor and offering few opportunities for renewed investigation. ©Robert Chandler reproduced with permission

c) Procedure for screening collected fossils by a nominated expert so that all scientifically important specimens and, if required, a selection of other representative specimens are donated to a registered museum.

d) Provision of a stockpile of waste fossiliferous rock shall be maintained at a specified location, this will be made available for educational and special interest parties.

The co-operation and support of the landowner has been critical to the successful delivery of these conditions. Working with the quarry manager, a system of bed numbering has facilitated the retention of located material from specific horizons and the quarry is regularly visited, sampled and recorded. An off-site stock pile has enabled more detailed examination of collected material and scientifically important specimens to be identified and retained. Up to 20m of the stratigraphy has been recorded (enabling a detailed stratigraphical review) and new sections have been cut deepening the extent of the succession exposed in the original SSSI to the base of the Bajocian. Also, whilst cutting and facing the Sherborne Building Stone, stone masons have encountered previously unrecorded crustacean remains in *Thalassinoides* burrow systems (which are now published).

4.1.3: Conservation outcome

Close working and co-operation between the site owner, mineral planning authority, researchers and Natural England (previously English Nature) has enabled the establishment of planning conditions that encompass on-going research and long term conservation of Frogden Quarry.

Planning conditions and collaboration have ensured access to the working quarry for on-going recording and sampling of temporary sections. Retention of scientifically important specimens has been facilitated and detailed new sections excavated and recorded. There is also provision to agree final restoration and conservation sections as the quarry reaches the end of its working life.

4.1.4: Further information

CHANDLER, R.B. & WHICHER, J., 2015. Fossils of Dorset, Inferior Oolite Ammonites, Lower Bajocian. Wessex Cephalopod Club, pp. 76.

CHANDLER, R.B., WHICHER, J., DODGE, M. & DIETZE, V., 2014. Revision of the stratigraphy of the Inferior Oolite at Frogden Quarry, Oborne, Dorset, UK. Neues Jahrbuch fur Geologie und Palaontologie 274, 133–148.

LARWOOD, J.G. & CHANDLER, R.B., 2016. Conserving classic geological sections in the Inferior Oolite Formation, Middle Jurassic of the Wessex Basin, south-west England. Proceedings of the Geologists' Association, 127, 132–145.

WHICHER, J.S.H., COLLINS, R.B. CHANDLER, M. DODGE & S. DAVEY. 2016. The fossil macrurous Crustacean *Glyphea* from within Thalassinoides burrows in the Inferior Oolite Formation of Frogden Quarry, Oborne, Dorset. Proceedings of the Geologists' Association, 127, 189-195.

Frogden Quarry SSSI (2015). Re-excavated to the base of the Bajocian. © Robert Chandler reproduced with permission

4.2: Philpot's Quarry

An active quarry (EA) in West Sussex

Conservation issues

- **The importance of early consultation with quarry operators and planners to ensure that geological conservation is considered with respect to extensions to extraction permissions and quarry restoration schemes.**
- **The use of planning conditions for the protection of geological sites.**

4.2.1: Site description

Philpot's Quarry is one of two quarries constituting Philpot's and Hook Quarries SSSI. The quarry exposes the Ardingley Sandstone Member of the Lower Tunbridge Wells Sandstone Formation (Hastings Beds Group), upon which rests the Grinstead Clay Formation. The base of the Cuckfield Stone forms the top of the exposed succession. This is a key site for the study of Lower Cretaceous sedimentary environments in the Weald Basin. More or less continuous study of the site over the past 60 years has facilitated the detailed sedimentological interpretation of the Ardingley Sandstone Member which is currently interpreted as representing a complex of fluvial channels spread across a sand plain. The Ardingley Sandstone Member has yielded occasional vertebrate fossils that include intact fish remains and Iguanodon bones. The transition to the Grinstead Clay reflects the landward migration of the shoreline with the pebble bed at the top of the Lower Tunbridge Wells Sand indicating migration of the strand-line as lake-levels rose with the onset of deposition of the Grinstead Clay Formation. Above this horizon, the succession is dominated by siltstones and mudstones associated with gutter casts, burrows, suncracks and soil horizons, and contains an assemblage of ostracods, gastropods and unioniid bivalves.

The quarry has been intermittently worked for building stone since the middle of the 20th century, and has been continuously worked over the past decade. The Ardingley Sandstone produces a range of sandstone products from rubblestone to high quality dimension stone for use in the conservation of buildings as well as modern builds. The Grinstead Clay Formation constitutes a thick overburden that requires removal before the stone can be extracted.

Northeast end of Philpot's Quarry SSSI, Sussex (2012). Near limit of permission showing the succession of the Grinstead Clay Formation forming a thick overburden on the Ardingley Sandstone Member, forming the bench, the lower part of the face and the floor of the quarry. ©Natural England/Dave Evans

4.2.2: Challenge and actions taken

The presence of thick overburden and the generation of a substantial quantity of waste stone at Philpot's Quarry has meant that as the working face migrates, the void space created is back-filled with quarry waste. This means that exposures cannot be easily retained, and ideally they should be recorded before they are covered in waste material. By 2012 the permitted reserve at Philpot's Quarry was running out, and because of the limited working space, quarry waste was being stored outside of the working areas. In order to maintain the viability of the quarry, the operators started to prepare an application for an extension to the Minerals Permission. It was proposed to work the extension in a series of phases from southwest to northeast along the northwest side of the old permission area. These would be backfilled with quarry waste as working progressed.

Since the material returned as waste has a greater volume than the rock that was originally extracted (despite the removal of viable stone), the volume of void space remaining at the end of the operation will be relatively small. Since the phasing of working opens up areas with progressively deeper overburden, the final working area will consist of a face formed by several metres of the Ardingley Sandstone Member, with several metres of the Grinstead Clay Formation resting upon it. The latter, being unstable would need grading back to a lower angle, generating further waste that would have to be placed in the void space. Thus, while the extraction of stone at Philpot's Quarry provides plenty of opportunity for the study and recording of features as the quarrying progresses, there

is a high level of risk that exposure will be very limited or non-existent by the time the reserve is exhausted. Since the extant mineral permission allowed for the complete infilling of the quarry, the only option for retaining exposure would be through any provisions that could be included in the permission for the extension of the workings.

Working with the consultants for the quarry operators, the problems associated with the large amount of waste generated by the operation were reviewed and a design developed that was aimed at retaining a series of exposures representative of the succession present at Philpot's. The exposures would be formed to profiles and overall heights that could be maintained in the long term without presenting stability or health and safety issues. This will be initiated with the retention of a permanent exposure in the southwest corner of the Phase I area. This is expected to provide access to the lower horizons of the Ardingley Sandstone Member exposed in the quarry. An exposure at the terminal end Phase 1 will be configured to provide long term stable features with access to the upper part of Ardingley Sandstone Member and the base of the Grinstead Clay Formation. Finally, at the northern limit of Phase 1b a stable and accessible exposure will be developed in the Grinstead Clay Formation.

4.2.3: Conservation outcome

Early stage consultation resulted in the development of a quarry extension in which the geological interest features are retained as a series of complementary exposures that will not be compromised by instability issues or conflicting restoration objectives. Access to these features would have been almost entirely lost in the original quarry. Despite the ultimate loss of the original exposures in Philpot's Quarry, the extension provides opportunities to study and record new features as extraction progresses. This may mean that the extent and the geometry of the large-scale structures present in the Ardingley Sandstone Member are better understood. The continued existence of these exposures will also mean that Philpot's Quarry will remain available as a classic site for the investigation of Wealden palaeoenvironments.

4.2.4: Further information

RADLEY, J.D. & EVANS, D., 2005. A future for Philpots Quarry SSSI. Earth Heritage 24, 17–18.

RADLEY, J.D., 2006. A Wealden guide 1: the Weald Sub-basin. Geology Today 22, 109–118.

4.3: Briton's Lane Quarry SSSI
An active gravel pit (EA) in Norfolk

Conservation issues

- **The problems with retaining exposures in unconsolidated sediments**
- **The use of the planning system to influence the long-term conservation and management of a geological feature**

4.3.1: Site description

Briton's Lane Quarry is a working quarry extracting gravel and sand on the southern side of the Cromer Ridge southeast of Sheringham. The quarry is selected as the stratotype for the Middle Pleistocene Briton's Lane Formation, which constitutes the uppermost unit of the Albion Glaciogenic Group. The Briton's Lane Formation consists of a succession of sands and gravels that truncate and drape the pre-existing sediments in the Cromer and Mundesley districts. In the quarry, up to 40m of generally planar bedded sand and gravel sheets are exposed. Occasional cross-bedded units are present, as are small, shallow channel fills. Gravel trains of various grades (up to large cobbles) occur throughout, whilst palaeosoil horizons are developed towards the top of the succession. The floor of the workings rest on an underlying till (the

Face on eastern side of the southern part of Briton's Lane Quarry SSSI, Norfolk. These steep and high slopes have no permanent exposures and are being allowed to revert to heathland. The slopes form from bench failure, so that much of the original face is covered in a layer of talus that varies in thickness across each of the original benches. ©Natural England/Dave Evans

Worked faces at northern end of Briton's Lane Quarry. Final faces form a stack of benches on each of which, talus accumulates. ©Natural England/Dave Evans

Bacton Till Member of the Sheringham Cliffs Formation). The environment in which the Briton's Lane Formation was deposited is interpreted as a waterlain ice marginal fan situated at the northern, ice-proximal, margin of the Cromer Ridge.

4.3.2: Challenge and actions taken

Briton's Lane Quarry contains extensive exposures of the Briton's Lane Sand and Gravel Formation and occasionally exposes the contact with the underlying Bacton Till Member of the Sheringham Cliffs Formation. The continued working of the quarry in a northerly direction may provide further temporary exposures of the underlying till while continuing to generate fresh exposures of the sands and gravels, facilitating further observation of the form and geometry of the bed-forms as well as the nature of the clasts. However, given the unconsolidated nature of the sediments being worked, the retention of exposures is problematic since if not supported or battered to a stable angle, the faces will fail, generating an accumulation of talus which will obscure the features.

The quarry has been operational since the 1940s and had an Interim Development Order (IDO) planning permission (expiring in 2042). There were few conditions associated with the permission and only limited control over the nature of any restoration. The site was the subject a Renewal of Minerals Permission (ROMP) to update the conditions which would also apply to an application to extend the workings eastward. This meant that it was possible that access to the interest features and a restoration sympathetic to the geological interest could become of the minerals permission, rather than being in the gift of the operator.

The specific allocations of mineral sites within the Norfolk Minerals and Waste Development Framework identifies land next to Briton's Lane Quarry for future extraction up to the end of 2026. This runs beyond the lifetime of Briton's Lane Quarry at its expected future annual extraction rate.

The importance of Briton's Lane Quarry SSSI and the broader geological significance of the Cromer Ridge are clearly recognised in the policies set out in this allocation and any planning application needs to be compliant. This includes:

- Future working should avoid the development of excessively steep faces.
- Retention of exposures for geological study and the maintenance of, or where possible, the improvement of the condition of the SSSI.
- Arrangements for access to the site for the purpose of study.
- Interpretation boards showing details of the glacial and peri-glacial geology of the site.
- A formal aftercare agreement (through a section 106 legal agreement) for at least 25 years after extraction has ceased must be agreed.

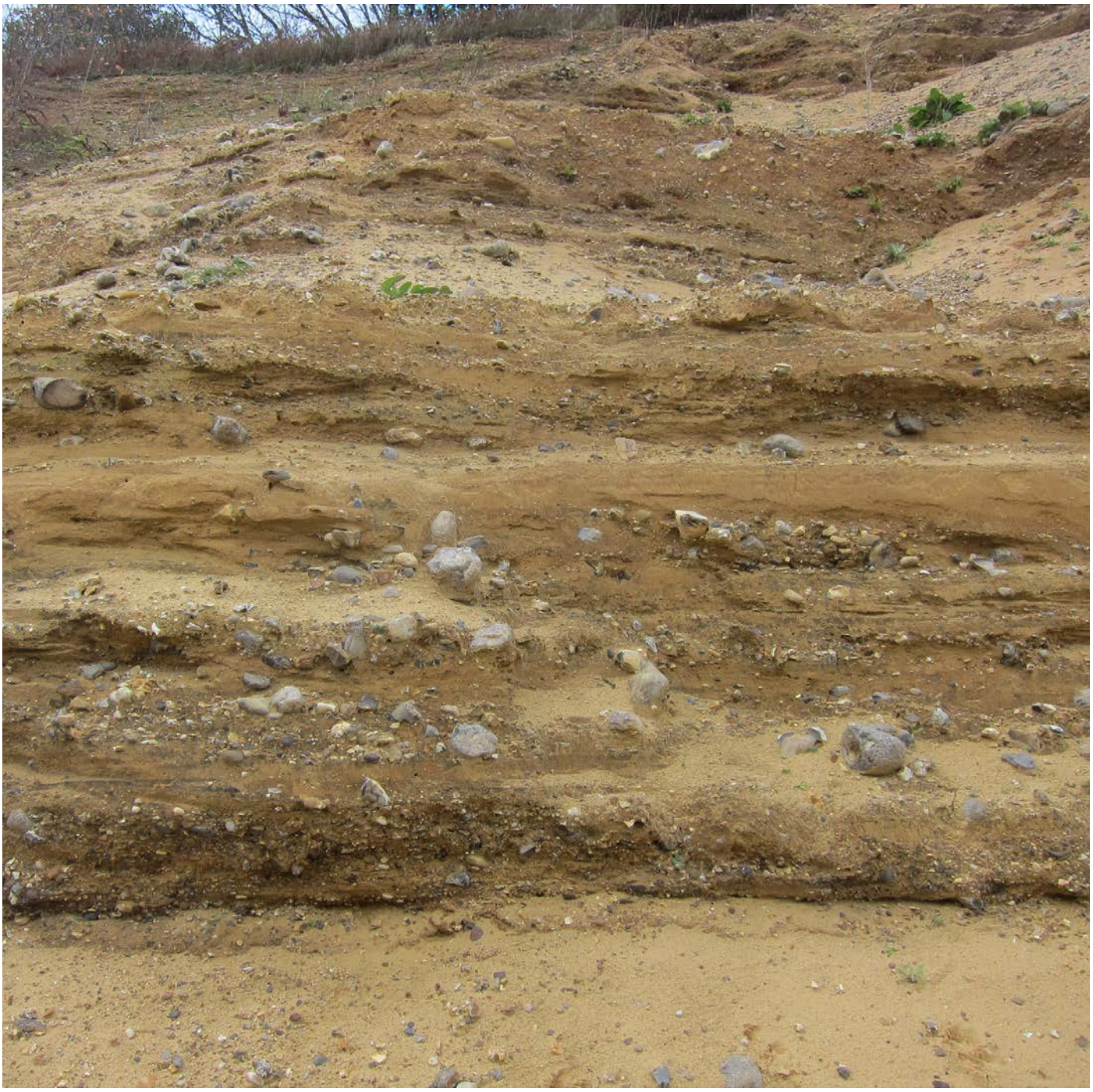
Permission for the eastern extension of Briton's Lane Quarry was granted in 2019. The watching brief report for the first year of extraction has now been completed showing high resolution images of the stratigraphy of the new faces and details of key features.

4.3.3: Conservation outcome

Whilst the current operators of Briton's Lane Quarry are sympathetic to the requirements for managing the geological interest of the site and welcome geologists and study groups, the long-term security of the geological interest lies with revision of the planning conditions for the permission. The policies and conditions for the new minerals allocation adjacent to the SSSI ensure that, even if it proves not to be possible to retain adequate exposures within the SSSI as a consequence of the antecedent conditions this is far more likely to be attained in the extension, as it has been planned into the new permission from the beginning, and can be integrated with other elements of the final restoration (access, heathland restoration, landscape, interpretation).

4.3.4: Further information

Jackson, M. 2013. Norfolk Minerals and Waste Development Framework: Minerals Site Specific Allocations Development Plan Document. Norfolk County Council.



Gravels and sands of the Briton's Lane Sand and Gravel Formation showing planar units with trains of gravel and flint cobbles forming small channels. ©Natural England/Dave Evans.

4.4: Kings Dyke Nature Reserve

A disused brick pit (ED) in Whittlesey, Cambridgeshire

Conservation issues

- **Managing a disused quarry (ED) within a complex of active quarries (EA) and manufacturing plant**

4.4.1: Site description

Kings Dyke Brickpit forms part of the complex of quarries extracting Oxford Clay for brick production to the west of Whittlesey, near Peterborough, Cambridgeshire. The site consists of the brickworks, situated on the floor of a worked out pit at the centre of the complex, connected via a conveyer belt to the current extraction site at Must Farm, about a kilometre west of the brickworks. Many of the older pits where extraction has ceased are now partially or completely flooded, and with the exception of the current extraction areas, the only area where extensive exposures of the Oxford Clay Formation remain are in the pit containing the brickworks.

The Peterborough Member of the Middle Jurassic Oxford Clay Formation contains an abundant and diverse marine fauna. The brick pits surrounding Peterborough have long been known for their fossil invertebrates, fish (including the giant *Leedsichthys*) and marine reptiles.

Conserved face exposing a section through part of the Peterborough Member of the Oxford Clay Formation forming part of the Nature Reserve within Kings Dyke Brick Pit, Whittlesey, Cambridgeshire. ©Natural England/Mick Murphy

Fossil collecting area at Kings Dyke. Fossiliferous material unsuitable for brick-making is transported to this location to form a fossil store; here being explored by members of a Geologists' Association field visit. ©Natural England/Colin Prosser

4.4.2: Challenge and actions taken

Health and safety issues in relation to the operating quarries and factories, as well as the disused pits means that although the operator will facilitate access for research purposes, casual entrance to the pit is not possible.

The Kings Dyke Nature Reserve was established in 1999. This includes areas of open water and associated habitats including freshwater, open ground, scrub and woodland. Recognising the importance of the Oxford Clay in the Peterborough area, geological sections were carefully incorporated into the Reserve, providing a safe area for visitors outside the working pit.

The geological area takes the form of an exposure of the Peterborough Member of the Oxford Clay Formation that is fenced off but can be accessed via a gate. The exposure was prepared by clearing weathered mudstone from the face. Given the nature of the rock this will need to be repeated occasionally so a reasonably fresh exposure is to be maintained.

Adjacent to the exposure is an area set aside for fossil collecting. The fossil collecting area consists of material from the working quarry that is unsuitable for brick-making. It is made up of sediments from the top of the Kellaways Formation and the base of the Peterborough Member. These contain numerous belemnites, *Gryphea*, well-preserved if largely flattened ammonites, and occasionally the teeth and vertebrae of marine reptiles and form a fossil collecting resource. The fossil collecting area is regularly replenished or turned over in order to provide fresh material.

There are two interpretation boards positioned on a platform facing views of the other side of the quarry and interpreting the geology of the Oxford Clay and its fossil fauna.

Access to the Nature Reserve, the and the fossil collecting area is free of charge, but requires a permit which can be obtained by applying for membership of the reserve. This means that the reserve managers have a much clearer idea of site usage than they otherwise would. The nature reserve and fossil collecting resource are used regularly by local schools and fossil collecting from here figures in a number of summer activities for children.

4.4.3: Conservation outcome

The geological area representing the Oxford Clay Formation at Kings Dyke Brick Pit has been secured because it forms part of Kings Dyke Nature Reserve where access is managed, and entry into the operational areas of the adjacent workings can be effectively controlled. The relationship between the operator of the brickworks and the Reserve is such that fossil collecting resource is regularly replenished, and a managed exposure of the Peterborough Member has been retained.

4.4.4: Further information

- Kings Dyke Nature Reserve

Looking eastwards to the interpretation board and disused face in the Peterborough Member. Fences mark boundary of the Reserve. Path beyond gate provides access to an area containing *in situ* exposures of the Peterborough Member. ©Natural England/Mick Murphy

4.5: Wren's Nest SSSI and NNR

Restored disused quarries (ED) in the West Midlands

Conservation issues

- **Geological conservation in an urban environment**
- **The importance of community partnerships and involvement in managing and promoting disused quarry sites for geological conservation and education**
- **Inspiration through the arts and interpretation**

4.5.1: Site description

The Wren's Nest SSSI and NNR includes a number of disused limestone quarries, located in a heavily urbanised area of Dudley, West Midlands, in the heart of the Black Country. The Wren's Nest is internationally renowned for the wide range of fossils of Silurian age which have been discovered there, especially during the period it was worked between the 18th century and about 1920. The site has yielded a fauna of well-preserved corals, crinoids, brachiopods and trilobites. To date, over 600 different fossil species have been formally described from the Wren's Nest. There are significant rock exposures on the site, including reefs and several spectacular ripple-marked bedding surfaces. The limestone pillars and caverns of the Seven Sisters Mine (see separate case study) are also located within the Wren's Nest.

The Wren's Nest is an internationally famous geological SSSI, and was declared a National Nature Reserve (NNR) in 1956, one of the first NNRs in Great Britain declared solely on the basis of its geology. The Wren's Nest NNR is managed by Dudley Metropolitan Borough Council by agreement with Natural England.

4.5.2: Challenge and actions taken

The Wren's Nest NNR is located in the heart of an urban housing estate and is subject to the usual pressures that impact on areas of open space located in urban environments. A management team, based on the Reserve, perform a range of duties, including maintaining accessible exposures, vegetation management, maintenance of fences and footpaths, leading tours of the Reserve and maintaining relationships with the local community. A series of geological trails, interpretation boards, and sculptural interpretation have been put in place on the Reserve. Problems such as vandalism and fly-tipping result in ongoing maintenance work for the Reserve staff. All on-site interpretation and safety fences have been designed to be robust and vandal-proof, and

The conservation of unstable, steeply dipping beds, which expose spectacular ripple marks on the bedding planes, provides a particularly difficult challenge at the Wren's Nest. ©Natural England/Jonathan Larwood

considerable improvement has been achieved through community involvement. This is aimed at encouraging those who live locally to develop a sense of ownership and pride in the site, and in doing so, to help maintain and enhance, rather than abuse what is an internationally important geological reserve.

In order to manage fossil collecting, a Fossil Collecting Code has been established. Collecting fossils from the rock faces and the use of tools requires permission and only a few representative specimens may be collected from the loose scree. This allows visitors to enjoy the experience of collecting fossils without unduly depleting the resource.

Safety is a major issue on the Wren's Nest. Unstable rock faces and mine entrances are securely fenced off and viewing in these areas is only permitted from safe viewing platforms. The former mines here are also prone to collapse and areas above known mine tunnels are securely fenced off.

The wildlife of the Wren's Nest is promoted and managed alongside the geology, with the aim of providing the public with access and recreation as well as with an experience of nature. The site shows the close links between the geology and wildlife, demonstrating how bare geological faces and disused quarries can become wildlife habitats as well as geological resources. Some faces are maintained cleared of vegetation to

Fossil collecting on the reef knolls (Upper Quarried Limestone). ©Natural England/Jonathan Larwood

allow access to the geology, whilst others allow gradual succession of habitat and associated species.

At the Wren's Nest, the geological trail, accompanying handbook and a hands-on experience of geology provides the basis of interpretation. Ancient reefs, well-preserved fossils, a rippled sea-bed and spectacular caverns all help to inspire visitors, especially school children, for whom a teaching pack for the site has been produced.

In 2008, working with the 'Leaps and Bounds' charity, over 60 young people from the local estates of the Wren's Nest were brought together to devise and perform a unique musical play inspired by the geology and industrial history of the Wren's Nest and Dudley. The play was performed in the underground caverns of the nearby Castle Hill and had a transformative effect on the young communities of the area and the value placed on the Wren's Nest and its geology.

Further funding was also obtained from the Heritage Lottery Fund for the 'Ripples through time' initiative which delivered for the Wren's Nest new interpretation, art and sculptures, devised new guided walks, allowed the construction of new viewing platforms, and the delivery of an associated outreach programme for schools and local communities. Also established was a Friends of the Wren's Nest Group who volunteer and support the work of the Wren's Nest wardens and organised the recent

60 years of the NNR celebrations. Redevelopment of the warden's base is now anticipated with the provision of meeting and classroom space for visitors.

4.5.3: Conservation outcome

Wren's Nest NNR demonstrates how disused quarries can be managed and interpreted for public as well as for scientific and educational use. In both cases, enthusiastic local planning authorities, committed to managing the sites, have been critical to the success of the sites, as has been the involvement of local geological groups and the local community. Both sites have been very successfully developed as educational resources. The Wren's Nest NNR is now a key Geosite in the current Black Country UNESCO Global Geopark.

4.5.4: Further information

CUTLER, A., OLIVER, P.G. & REID, C.G.R. 2009. Wren's Nest National Nature Reserve Geological Handbook and Field Guide 2nd edition, Dudley Metropolitan Council and Natural England. 30pp

PROSSER, C.D. & LARWOOD J.G., 2008. Conservation at the cutting edge: the history of geoconservation on the Wren's Nest National Nature Reserve, Dudley, England. From: BUREK, C.V. and PROSSER, C.D., (eds) The History of Geoconservation. Geological Society of London, Special Publications, 300, 217-235.

View of reef knolls and houses of surrounding estates. ©Natural England/ Jonathan Larwood.

4.6: Swaddywell Pit

Disused quarry (ED) and nature reserve on the outskirts of Peterborough, Cambridgeshire

Conservation issues

- **The value of local organisations in securing, managing and facilitating access to sites**
- **The integration of the management of wildlife and geological features on a small Local Geological Site.**

4.6.1: Site description

Swaddywell Pit is one of a number of disused quarries in the Lincolnshire Limestone about two kilometres south of the village of Helpston in northern Cambridgeshire. The site has a long history as a quarry and was referred to in the early 19th century by the poet John Clare. With the exception of the western part of Swaddywell Pit all the quarries were landfilled during the 1980s.

The quarry lies on the southern side of the southern-most branch of the Marholm-Tinwell Fault and provides a number of exposures of the Lincolnshire Limestone Formation as well as its contact with the underlying silts of the Grantham Formation. The northern face of the quarry lies on or close to the fault, where a zone of strongly dipping beds represent part of a drag-fold associated with a fault down-thrown to the south.
In terms of the combination of features present, the site has a clear

Section on northern side of Swaddywell Pit showing cross-bedded oolites of the Lincolnshire Limestone Formation. The exposure forms part of the geological trail and is regularly cleared of vegetation such as brambles. ©Natural England/Dave Evans

Western face of pit with northerly dipping limestone showing a small fault. The boardwalk maintains access around the faces when the floor becomes flooded during the winter. ©Natural England/ Dave Evans

educational value whilst providing a representative element of the geology of the region.

4.6.2: Challenge and actions taken

Swaddywell was originally designated as a LGS in the mid-1990s, but the condition of the site and the difficulties gaining access to it meant that very there was very little activity in relation to the conservation of the geological features. Easy access to Swaddywell became possible after its acquisition in 2003 by the Langdyke Countryside Trust, funded by the Aggregates Sustainability Levy Fund. The site was restored as a nature reserve (as it had been for a period during the early part of the 20th century), but from 2007 onwards, the development and management of the geological aspects of the site became an important objective.

Initially, local geological expertise was used to survey the site and identify features that are easily observed and interpreted, such as cross-bedding and faulting. Features characteristic of the local development of the Lincolnshire Limestone Formation were also identified. This information was used to inform the development of interpretation including a geology trail, as well as being integrated into the overall management plan for the reserve. The trail takes the form of a circular route around a number of stops marked by numbered posts. The exposures are kept clear of vegetation through the work of volunteers as part of the overall management of the site. A herd of hebridean sheep also help to control scrub across the site. With the addition of a small 'classroom' at the eastern end of the quarry, the reserve is used by schools and other groups for educational visits that cover the biological and geological aspects of the site amongst other features.

4.6.3: Conservation outcome

Swaddywell Pit is one of the very few remaining quarries providing access to the Lincolnshire Limestone Formation in the Peterborough area. Other quarries are either operational or being landfilled, and are generally inaccessible to the public. The key to the conservation of Swaddywell Pit was its purchase by the Langdyke Countryside Trust which secured it from future uses that would be incompatible with the management of the biological and geological features it contains. Although primarily purchased for its biological interests, collaboration between the Langdyke Countryside Trust and GeoPeterborough has facilitated the inclusion and development of the geological features of the site so that they are integrated into the overall management and use of the site.

North face showing a stack of cross-bedded units of the Lincolnshire Limestone, and forming the downthrown limb of a drag fold generated by fault immediately to the north. The bottom of the face contains exposures of the underlying Grantham Formation. ©Natural England/ Dave Evans.

4.7: Horn Park Quarry SSSI and NNR

Disused quarry (ED) and finite fossil deposit (FM) in Dorset

Conservation issues

- **Conserving a finite resource vulnerable to collecting and development pressure**
- **Conserving geological sections within a light industry/business park development**

4.7.1: Site description

Horn Park Quarry SSSI and NNR, near Beaminster in Dorset, is one of the most famous and richly fossiliferous localities in the Middle Jurassic Inferior Oolite Formation of southwest England. It is the most complete exposure of the Aalenian to Bajocian succession in the region and is particularly noted for the unique Horn Park Ironshot Bed. The Horn Park Ironshot Bed comprises a series of planar erosion surfaces that includes a prominent hard ground surface forming a large platform containing a diverse and well preserved fossil invertebrate fauna, of which ammonites make a significant component.

Horn Park has been quarried for building stone since the 19th century. Extraction ceased in 2000 and planning permission was granted for the development of a business park on the quarry floor. Today the SSSI encompasses a lower and upper area (separated by a fault) that includes the business park. A smaller NNR was declared in 2009, enclosing the most sensitive (and complete) part of the site in the upper quarried area. It includes an area of unworked limestone that provides a complete representation of the stratigraphical succession.

4.7.2: Challenge and actions taken

Horn Park Quarry presents two significant challenges. Firstly, as the limestone has largely been quarried out, the remaining fossil resource is finite and particularly vulnerable to over-collecting and illegal collecting (this has been a problem in the past). Secondly, given this vulnerability, and the limited extent of the remaining sections, development of a business park has required careful and sensitive planning to retain access to the succession.

Following a detailed survey, the main faces in the upper quarry were re-exposed and benched, enabling access to the complete stratigraphical sequence. This area was securely fenced; restricting access to and demarcating the most sensitive area of the site during the construction of industrial units. As part of the development, car parking spaces

General view of Horn Park Quarry NNR showing fenced area with industrial units in background. ©Natural England/Jonathan Larwood.

were installed adjacent to the enclosed area in order to serve both the industrial units and visiting geologists. The fenced area was declared as a National Nature Reserve.

Since 2009 further improvements have been made by extending the exposure of the lower part of the sequence and excavating the upper part of the sequence in the back face. A small area of the lower limestones, including the Ironshot Bed, has been carefully stripped back and the fossils developed *in situ*. A secure box (with a weld-mesh lid) has been placed over this area. This approach allows visitors to view in detail and *in situ*, the diverse fossil fauna of Horn Park in stratigraphical order. The secure box cover also protects the revealed fossils from the potential risk of loss. Surplus material from the site investigation and clearance works has been left on site for visitors to collect from. Specimens have also been donated to the nearby Beaminster Museum where they have been incorporated into a geology exhibition and fossil educational boxes for the museum's work with local schools.

Boxed weld mesh cover protecting exposed fossil beds. ©Natural England/Jonathan Larwood.

Horn Park Quarry NNR, 2015. Protective cover (open) showing prepared beds of the Ironshot (Bed 5 down to Bed 4). ©Natural England/Jonathan Larwood..

4.7.3: Conservation outcome

- The scientific interest of Horn Park Quarry SSSI has been secured as part of agreed restoration and after use.
- The secure enclosure, with managed access, has successfully conserved the remaining resource, protecting it from unmanaged collecting and enabling the continuing educational and research use of the site.
- The protective cover provides a unique and secure opportunity to view fossils exposed *in situ*.

4.7.4: Further information

LARWOOD, J.G. & CHANDLER, R.B., 2016. Conserving classic geological sections in the Inferior Oolite Formation, Middle Jurassic of the Wessex Basin, south-west England. Proceedings of the Geologists' Association, 127, 132–145.

4.8: Gilbert's Pit SSSI and Riddlesdown Quarry LGS
Disused quarries (ED) in London

Conservation issues

- **Managing vegetation and scree build-up in disused quarries**
- **Managing access to steep faces in an urban environment**
- **Need for on-going management**

4.8.1: Site description

These two disused quarries in south London have similar management challenges, in particular, managing the accessibility of steep, high faces in an urban environment.

Gilbert's Pit SSSI, one of a network of former pits in the Charlton area, was worked for sand, gravel and chalk until 1938 and was subsequently partially infilled. Today Gilbert's Pit is owned and managed by the Royal Borough of Greenwich as a public open space adjacent to Maryon Park and is included on the south London Green Chain walk. The remaining steep and wooded slopes represent the most complete exposed section through Palaeogene strata in Greater London, in particular the Woolwich Formation (type locality) and Reading Formation. It is regularly visited by geologists and is used for training engineers involved in large-scale development projects (such as Cross Rail) as it demonstrates the variation in sub-surface lithologies that may be encountered in the London area.

Riddlesdown Quarry, on the North Downs near Croydon, is the finest remaining exposure of Cretaceous chalk in London with over 50m of the chalk succession exposed. This includes the Lewes Nodular Chalk and Seaford Chalk formations. Riddlesdown was worked until 1964 and is today owned by the London City Corporation, is a Local Geological Site and part of the Riddlesdown Common (biological) SSSI and the South London Downs NNR.

4.8.2: Challenge and actions taken

Both Gilbert's Pit and Riddlesdown have relatively high (20m+), steep faces that are difficult to access. Both have been encroached by woodland, vegetation and scree build-up since closure – impairing the visibility of and impeding access to the geological sections. Gilbert's Pit has also suffered high levels of erosion and scree build-up (in particular the collapse of the Blackheath Pebble Beds) as a consequence of ridge-top path erosion and parts of the eastern face being regularly used as a slide.

Gilbert's Pit - Eastern face showing build-up of scree (eroded Blackheath pebble Beds) and the slope eroded through its use as a slide. ©Natural England/Dave Evans.

Gilbert's Pit

Access: providing safe access, particularly to higher parts of the section, is very difficult. Informal ridge top and narrow paths provide routes to the upper parts of the section, and the lower parts can be approached by climbing the scree slopes. In 2016, following a geotechnical survey and assessment of potential access routes, a girder framed stepped access was constructed on the eastern face which for the first time has provided safe access to the middle and upper parts of the section.

Vegetation encroachment: since 2013 vegetation has been regularly managed by volunteers from the London Geodiversity Partnership with the help of the Royal Borough of Greenwich. Trees and underlying scrub have been cut back to open up two views in the eastern and southern faces which are maintained through regular conservation days.

Scree build-up and erosion: this has been a particular challenge. Erosion of the ridge-top path above the eastern face breached the Blackheath Pebble Beds. Further erosion has been caused by the slope being used as a slide leading to a significant build-up of scree at the

Gilbert's Pit - step construction in progress in area of scree build-up and slide. ©Laurie Baker reproduced with permission

Gilbert's Pit - completed stairways and platforms © Natural England/Julie Russ

Riddlesdown Quarry 2010: steps along base of exposures. ©Geologists' Association/Diana Clements reproduced with permission

slope base. Construction of an exclusion fence failed to prevent access and erosion continued. The 2016 stepped access was constructed over the slide slope with the additional purpose of curtailing the on-going erosion.

Riddlesdown Quarry

Following a resurvey of the chalk stratigraphy in 2010 a programme of conservation work was agreed for Riddlesdown. Vegetation was cleared by volunteers from the London Geodiversity Partnership and a set of wooden fronted steps with handrails constructed to provide access to the higher parts of the section. A flock of goats was then introduced as ideal grazers for these steep chalk faces – they successfully kept the vegetation in check until the flock was retired in 2013. By 2016 key parts of the section were once more concealed by vegetation. London Geodiversity Partnership volunteers have now returned to continue the vegetation management with regular visits planned for the future.

4.8.3: Conservation outcome

Gilbert's Pit and Riddlesdown demonstrate the challenge of managing disused quarries in urban areas. The geological value has declined with the encroachment of scrub and woodland, and build-up of scree which has been exacerbated by visitor erosion. Construction of steps has provided safer access to upper parts of the section (and decreased erosion rate) at Gilbert's Pit. On-going clearance of vegetation is essential. At Riddlesdown the value of goats in maintaining geological sections was demonstrated, otherwise, regular visits by volunteers have been essential. Both sites are currently maintained in good condition, are described in geological field guides to the London area and new interpretation has been installed at Gilbert's Pit.

4.8.4: Further information

BAKER, L., 2017. Opening access to pit's geological past. Earth Heritage, 47, 36-37.

CLEMENTS, D., 2012 (Ed.). The Geology of London, Geologists' Association Guide No. 68

CLEMENTS, D., 2017. Throwing new light on London's rare Chalk exposure. Earth Heritage, 47, 34-35.

Riddlesdown Quarry 2010: goats controlling vegetation. ©Geologists' Association/ Di Clements reproduced with permission

4.9: Woodeaton Quarry SSSI
A disused quarry (ED) in Oxfordshire

Conservation issues

- **The restoration of a disused quarry with a complex history of use**
- **The use of landfill to manage the stability of over-steepened quarry faces and retain access to exposures**
- **Integration of geological and biological interests in the restoration.**

4.9.1: Site description

Woodeaton Quarry SSSI is a moderately large disused quarry that was worked for aggregate and lies just to the north of the village of Woodeaton, a few kilometres northeast of Oxford. The quarry exposed horizons belonging to the Charlbury Limestone Member of the Sharp's Hill Formation, upwards through to the base of the Forest Marble Formation, and thus includes the whole of the Middle Bathonian as well as part of the Upper Bathonian. Many of the horizons (the Charlbury Limestone Member and White Limestone Formation in particular) contain an abundant and diverse marine fossil assemblage, while the Rutland Formation and the Bladon Member of the White Limestone Formation have yielded a variety of vertebrate and micro-invertebrate remains that include fish, amphibians, reptiles, dinosaurs and early mammals.

Western face of Woodeaton Quarry SSSI, Oxfordshire, showing section through most of the Blisworth Limestone Formation and base of the Forest Marble Formation. The very top of the face cuts through a soil bund, demonstrating that the face was worked right up to the edge of the permission, leaving a high and unstable face. Most of the exposure is inaccessible. Partial infill as ramps against the face will improve accessibility as well as the long-term stability of the face. ©Natural England/ Dave Evans

Western face of Woodeaton Quarry toward the southern end of the site. The eastern half of the quarry has been left with a thick overburden of quarry waste that drained into a sump lying below the level of the water table. The main face above the sump exposes the Taynton Limestone Formation with the Rutland Formation above. An exposure down to the Taynton Limestone Formation will be retained in this area. ©Natural England/Dave Evans

4.9.2: Challenge and actions taken

Woodeaton quarry has been worked intermittently over a long period and has a complicated and controversial planning history. As a consequence, the site had been worked to the permission boundaries, leaving steep and high faces rather than a set of benches that would contribute to the stability of the final faces and provide access to the full succession exposed in the quarry. In addition, large piles of spoil and waste were left covering parts of the site and the deepest parts of the quarry lay below the water table. Despite this, the succession remained fully exposed from the Forest Marble Formation to the base of the Taynton Limestone Formation. With its close proximity to the village of Woodeaton, the site was regarded as a liability, presenting a void with sheer faces and a water hazard.

With a change of ownership during 2011, an opportunity to achieve a long-term solution to the conservation of the geological interest through partial landfill, landscaping and restoration of the quarry. Collaboration

between the new owner and the geological community led to a design that made use of imported waste and waste already within the quarry into design slopes that would act to support the remaining faces, direct water into one area of the site, and facilitate access to the full succession. These plans inevitably led to a much reduced total area of exposed rock, but also meant that parts of the succession (particularly the Blisworth Limestone Formation) that were exposed but inaccessible, would become accessible. Some of the quarried waste consists of fossiliferous limestone from the Charlbury Limestone Member and the Blisworth Limestone Formation. This will be set aside as a fossil collecting resource within the restored site. The restoration for the remainder of the site involved the enhancement of a range of habitats already present on the site so as to form a mosaic and increase the species diversity.

As the scheme progressed it became clear that the remaining quarry faces were becoming unstable and were likely to fail completely over the next few years. As the remaining faces abutted a public road, and there was no location where safe, new exposures could be developed, and a variation of the Planning Permission to totally infill of Woodeaton Quarry was reluctantly accepted. As of 2020, the remaining faces were entirely battered and the remaining void nearly filled. Recording has taken place (Wills et al. 2019) and material set aside for later study, but the site itself is gone.

4.9.3: Conservation outcome

Although Woodeaton Quarry has always contained extensive exposures of Bathonian sediments, its planning status and physical condition meant that the geological interest of the site was under a constant threat from inappropriate after-uses. Had the instability of the remaining faces not proved to be such a problem, restoration, although reducing the total area of exposure, would have improved physical access to the interest features and secured the site from future uses that would have resulted in its loss.

This case, however, serves as an object lesson regarding the importance of establishing a restoration plan sympathetic to the retention and management of geological features early in the planning life of the quarry.

4.9.4: Further information

EVANS D. H. 2004. Accessibility issue tested. Earth Heritage, 21, 8.

WILLS, S., BERNARD, E.L., BREWER, P., UNDERWOOD, C.J. & WARD, D.J. 2019. Palaeontology, stratigraphy, and sedimentology of Woodeaton Quarry (Oxfordshire) and a new microvertebrate site from the White Limestone Formation (Bathonian, Jurassic). Proceedings of the Geologists' Association, 186, 170-186.

4.10: Webster's Claypit SSSI (DENOTIFIED)

A landfilled disused quarry (ED), West Midlands

Conservation issues

- **The impact of landfill on a geological exposure in a disused quarry.**
- **The failure of the planning system to protect an SSSI in a situation where a planning permission predates the notification of the SSSI.**

4.10.1: Site description

Webster's Claypit lay within the city of Coventry. The site was notified as an SSSI for Carboniferous sandstones and mudstones of the Enville Member. The exposures at Webster's Claypit represented the only available exposure of alluvial plain deposits within the Enville Member. The site has also yielded a distinctive fossil flora, reflecting more humid conditions than other sites of the same age and was considered the best site in Britain for studying Upper Palaeozoic conifers.

Webster's Claypit, West Midlands, showing good exposure of geological features. ©Natural England/ Colin Prosser

Webster's Claypit in 2016. Now permanently infilled with total loss of the exposure of nationally important geological features. ©Natural England/Colin Prosser

4.10.2: Challenge and actions taken

Webster's Claypit was notified as an SSSI in 1986, a short while after planning permission to landfill the site had been granted. Therefore, under planning law, the planning permission for landfilling the site took precedence over the statutory nature conservation designation and the associated legislation aimed at conserving the SSSI.

Although legally powerless in this situation, English Nature, the relevant national conservation agency at the time, made representations to the local planning authority to try and persuade them to retain a conservation section as part of the planned landfill of the site. The local planning authority, however, wished to see the quarry totally infilled in order to provide a much-needed greenspace area with sports pitches within this urban setting.

Arguing a case for the accommodation of the geological interest within the site was made difficult by both the local importance attached to the proposed greenspace end-use of the site and by health and safety concerns arising from having a rock face included within an inner-city recreational area.

4.10.3: Conservation outcome

Although the site was designated as an SSSI, the pre-existence of a planning permission for landfill meant that the local planning authority was in full control of the conservation outcome. Despite English Nature and other parties, such as the Warwickshire Wildlife Trust, making strong pleas for the site to be conserved, no variance from the planned total landfill was forthcoming and by 1993 the site was fully landfilled and the geological exposures lost. In 2012, many years after the landfill was complete, the site was de-notified as an SSSI.

It is reasonable to assume that the geological importance of Webster's Claypit was not fully appreciated by the local planning authority or the local community. This illustrates the need for geologists to undertake activities that raise the awareness of decision-makers of the importance of geology and designated geological sites.

Webster's Claypit is a rare example of a geological SSSI where the notified geological features have been completely lost to science.

4.10.4: Further information

PROSSER, C. 2003. Webster's Clay Pit SSSI- going, going gone ... but not forgotten. Earth Heritage, 19, 12.

4.11: Church Cliff and East Cliff, Lyme Regis

An engineering project within the West Dorset Coast SSSI and Dorset and East Devon Coast World Heritage Site (EC, IA)

Conservation issues

- **The value of consultation and dialogue in the development of a large engineering scheme**

4.11.1: Site description

The cliffs and foreshore either side of Lyme Regis provide extensive exposures of the Early Jurassic, Blue Lias Formation, consisting of a sequence of alternating limestone and mudstone. Studied for over 250 years, these rocks are celebrated for their fossil invertebrate, fish and marine reptile assemblages. The Charmouth Mudstone Formation, resting on the Blue Lias, forms the upper levels of the cliff slope, and is turn capped by the Upper Greensand at the crest of the slope.

To the east of Lyme Regis are the complex of slope failures that form the Black Ven landslip system.

4.11.2: Challenge and actions taken

During the 19th and early 20th century, the quarrying of the cliffs and foreshore for stone and cement contributed to the reactivation of ancient landslips. The quarrying combined with accelerated rates of wave erosion promoted the removal of the toes of the relict landslips perched on the slopes above the cliff crests. With their toes removed, the landslips were partially reactivated. By the late 20th century, the sea walls and groynes fronting Church Cliff had begun to fail and the Black Ven landslip complex to the east had started to propagate westwards, threatening properties and infrastructure in the eastern part of Lyme Regis.

As part of a wider strategy for mitigating ground instability around Lyme Regis, a major stabilisation scheme was proposed for Church Cliff and East Cliff in order to secure the A3052 and properties on the east side of the town. This area lies within the West Dorset Coast SSSI and the Sidmouth to West Bay Special Area of Conservation (SAC) and the scheme would potentially impact on the geological and biological interests of the SSSI and SAC.

Scheme options with different impacts on the SSSI and SAC were submitted for public consultation. These ranged from ‘do nothing’ to the construction of extensive areas of rock armour on the foreshore combined with a new seawall seaward of the old wall, with terracing, drainage, piling and soil-nailing stabilising the slopes above the seawall/cliff crest.

Church Cliff and East Cliff in 2008. In the distance, the Spittles landslide consisting of mudstones belonging to the Charmouth Mudstone Formation with its back scar in the Upper Greensand. Foreshore of ledges in the Blue Lias Formation with a failed groyne-field. Cliffs in the Blue Lias Formation obscured by scoured and corroding seawall, with unstable slopes above. ©Natural England/Dave Evans

The preferred option was for a new sea wall sufficiently wide to provide public access along the top of the wall. This was combined with a rock revetement forming an apron seaward of the wall and extending in front of the cliff for 60 metres beyond the eastern end of the wall. Landslips above East Cliff were to be re-graded to regular terraces with deep counterfort drains. Land above Church Cliff was to be stabilised with an earth bund and piling.

Although the loss of foreshore exposure from this scheme was relatively small, and the old sea wall had obscured the western end of the cliff exposure since the 1960s, the oldest Blue Lias exposed would be lost by the advance of these structures. Furthermore, the area below Church Cliff was known to have yielded a number of marine reptiles in recent decades. Engineering of the slopes above the cliff crest would not have made much difference to the distribution and quality of exposure of the Charmouth Mudstone Formation, but would impact significantly on the extent and functioning of the western end of the Black Ven GCR site (Mass Movement), and on the SAC features in this area; relying on geomorphological processes to maintain the habitat.

An amended scheme to reduce these impacts was proposed after consultation with Natural England and West Dorset District Council. The plans to use rock revetments were withdrawn, except at the eastern end of the seawall, where they were used as protection from outflanking. The extent of works above the cliff slope was reduced to substantially smaller footprint on the Black Ven GCR site. Works above Church Cliff were modified by the emplacement of an earth berm as a toe weight, combined with deep piling to strengthen the slopes and inhibit the westward propagation of further slope failures. Although the seawall was advanced seaward, its footprint took up 0.2% of the foreshore rather than the 1%, of the preferred option.

Google Earth image of completed scheme with access route on the top of the seawall together with access ramps onto the foreshore. Exposures of the upper part of the Blue Lias Formation within reach from the access on the seawall. Path leading from carpark down to seawall acts as pedestrian access into the centre of Lyme Regis and also marks the eastern limit of the stabilisation works on the upper slopes. ©Google Earth visited 2018. Imagery Date 8/15/16.

Provision was made for a watching brief to recover significant fossil remains that might be discovered as well as for the recording of geological features during the construction phase.

4.11.3: Conservation outcome

In consultation with the statutory bodies, the impact of the preferred scheme on the geological and biological interest features was considerably reduced through the revision of the scheme to one that provided protection for 50 years but with a substantially reduced footprint on the geological and biological features. Whilst minimising the impacts of the scheme, it has also provided some benefits. These include access to the upper part of the Blue Lias Formation, improved and safer access to the foreshore, access onto the Spittles, and interpretation boards sited along the seawall walkway.

4.11.4: Further information

MOORE, R., STANNARD, M. and DAVIS, G. 2016. East Cliff, Lyme Regis, UK: Balancing the needs of coastal protection, landslide prevention and the environment. pp 1477-1484, in AVERSA, S., CASCINI, L., PICARELLI, L. and SCAVIA, C. Landslides and Engineered Slopes. Experience, Theory and Practice: Proceedings of the 12th International Symposium on Landslides (Napoli, Italy, 12-19 June 2016). Volume 3. CRC Press, Taylor & Francis.

4.12: Fairlight Cove

Coastal exposures (EC) in East Sussex

Conservation issues

- **The impacts on the geological interest features of a range of strategies designed to inhibit cliff failure, landslips and crest retreat and protect property.**

4.12.1: Site description

Fairlight Cove lies toward the eastern end of Hastings Cliffs to Pett Beach SSSI. The SSSI is a mixed geological and biological site extending over a distance of 10 km and consists of cliff, foreshore and land behind the cliffs. The cliffs are high and sheer at the western end of the site, at the eastern end, around Fairlight, complex landslip systems are also present. Geologically, the site provides almost continuous exposures of the Early Cretaceous, non-marine, Ashdown and Wadhurst Clay formations over a distance of seven kilometres. This site is of particular importance for the interpretation of Wealden sedimentary environments, and is the source of numerous fossil vertebrates, as well as a diverse macroflora. Active coastal erosion continuously renews the palaeontological resources of the site. Much of the land adjacent to the coast along this stretch is undeveloped and forms part of a country park, but toward the eastern end of the site, the village of Fairlight Cove lies adjacent to the crest of the cliff for a distance of approximately two kilometres. The cliffs and foreshore at Fairlight Cove expose the Haddock's Rough Unit of the Ashdown Formation: a set of laterally accreted trough cross-bedded sandstones and bioturbated silts and muds with an erosional base. This unit is

Rock berm fronting eastern end of Fairlight Cove with cliffs exposing the Haddock's Rough Unit of the Ashdown Formation behind the berm. ©Natural England/Jonathan Larwood

Exposures of the Haddock's Rough Unit seen during 2013. Note the accumulation of talus well up the cliff face and the development of vegetation on the talus. The gap between the berm and the cliff face contains a reed bed, indicating that is often flooded with brackish water. ©Natural England/Dave Evans

exposed in elevation-view in the cliff and in plan-view on the foreshore, facilitating a three dimensional interpretation of the structure.

4.12.2: Challenge and actions taken

The retreat of the cliff in Fairlight Cove during the 1980s resulted in the crest of the cliff encroaching onto properties immediately behind the cliff and the access road for the properties. Initially, limited protection was proposed for three of the properties, but in 1988, a scheme involving a 500 m stretch of toe protection to the height of 3 m along the base of the cliff was proposed. This would have obscured the lower part of the Haddock's Rough Unit. The Nature Conservation Council (NCC) (one of Natural England's predecessor bodies) advised that inspection chambers would be necessary in order to safeguard the geological interest. The proposal for toe protection then was replaced by an alternative scheme consisting of an offshore berm formed by a 500 metre long rock revetment. The NCC accepted this scheme but negotiated for an agreement by which talus and vegetation would be regularly cleared at a number of locations along the cliff face. No agreement was made as NCC were expected to take on any liabilities resulting from the consequences of any further cliff failure.

A major landslip system that had developed during 1995 at the western end of Fairlight Cove, evolved into a major complex of slides that by the early 2000s had receded 85 m landward, with the consequent abandonment and destruction of several cliff-top properties as well as infrastructure. With the landslide predicted to continue to evolve, threatening further properties, a scheme to mitigate ground instability

West end of Haddock's Rough Unit just to the east of the Fairlight Cove Fault in 2007. Tops of cross-bedded units visible but talus and vegetation well-developed over much of the lower part of the exposure. ©Natural England/Anna Wetherell

was developed. The scheme required the construction of a toe revetment to support the landslip, as well as the re-profiling of slopes and the installation of drainage. The location of the scheme lay to the east of the axis of the Fairlight Anticline, the core of which exposes the oldest units of the Ashdown Formation within the SSSI. English Nature, the successor to the Nature Conservancy Council, objected to the scheme on the grounds of the impact to the geological interest, and the British Geological Survey were commissioned to compare the successions on either limb of the anticline in order to assess the impact on the interest features. The comparison demonstrated that an overall transition was present in which channel fills predominated to the west, while lagoonal and over-bank deposits dominated in the east. Since the landslide and mitigation scheme were at the extremity of the eastern limb of the anticline the impact on the interest features was considered to be relatively insignificant. With some further mitigation relating to minimisation of impacts to the foreshore geology during the construction of the scheme, the objection was withdrawn.

By 2015, the lack of beach sediment fronting the cliff meant that erosion of the cliff foot was accelerating and causing outflanking of the landslide remediation, both threatening properties and the pumping station built to drain the landslide, thus putting the landslide mitigation scheme under threat. A third berm consisting of rock armour was installed during 2016; thus filling the gap between the two schemes.

Construction of western berm forming toe weight of landslide. Landslide being re-profiled prior to installation of drainage. ©Natural England/ Anna Wetherell

4.12.3: Conservation outcome

Most of the frontage of Hastings Cliffs to Pett Beach SSSI lacks any development and is subject to the effects of natural coastal processes, which maintains the geological exposures. The presence of Fairlight Cove with housing built close to the crest of the cliff has resulted in this stretch of the site being subject to schemes designed to protect properties by halting further recession of the cliff crest. Now decoupled from wave-erosion, the remaining exposures behind the berms will continue to accumulate talus with the further colonisation of vegetation. Whilst it is physically possible to remove talus and vegetation from the cliff-faces there exist legal barriers to carrying this out. Positive outcomes achieved include the avoidance of toe protection along the eastern frontage of Fairlight and mitigating the impacts of storage and vehicle movement on foreshore exposures during the construction phases of the schemes.

4.12.4: Further information

DOYLE, P. 1989. Inspection chambers for Fairlight Cove? Earth Science Conservation, 26, 25.

EVANS, D. H. 2006. Close to the edge. Earth Heritage, 26, 7.

4.13: Easton Bavents

A coastal cliff and foreshore site (EC), Suffolk

Conservation issues

- **Conflict between geoconservation and coastal protection on an actively eroding coastline**
- **Challenges arising from coastal protection undertaken outside of the planning system**

4.13.1: Site description

Pakefield to Easton Bavents SSSI is nationally important for a number of features including its geology, coastal geomorphology and a range of coastal habitats and species. Easton Bavents lies at the southern end of the SSSI and is a stratigraphically and palaeontologically important sequence of Pleistocene sediments exposed along a stretch of eroding coastal cliffs and foreshore. The geological features exposed include the three major elements of the Norwich Crag Formation, namely the Chillesford Church Member, the Easton Bavents Member and the Westleton Member. It is also important for its Pleistocene vertebrate assemblages which are rare in northern Europe for this part of the Pleistocene.

Aerial photograph of the large coastal protection structure taken in September 2005 and showing its extent and impact in obscuring the geological features exposed in the cliff and foreshore. ©Mike Page, www.mike-page.co.uk reproduced with permission

The remains of the berm during 2007. Showing its composition of soil and building debris. Maintenance of the structure had ceased by this time and natural coastal processes were starting to re-expose the geological features in the cliff. ©Natural England/Patrick Robinson

4.13.2: Challenge and actions taken

In simple terms, the conservation objectives for the cliff and foreshore exposures at Easton Bavents are that they remain clear and accessible for scientific study and educational use. In practice, this involves maintaining the natural processes that are working to retain clean geological exposures and discouraging the construction of any structures against the cliff-face that may obscure the features for which the site is nationally important. However, concerns from some residents of the small coastal settlement of Easton Bavents, about the impact of on-going coastal erosion on their cliff-top properties, led, in 2003, to one of them taking action to try and stop, or at least slow, the erosion. This action, taken without first applying for the necessary planning consent, involved the construction of a large coastal protection structure 1km long, 8 meters high and made up of tipped soils, building waste and similar material. Although subject to coastal erosion itself, it was maintained between 2003 and 2005 by on-going tipping.

The structure obscured the geological features exposed in the cliff. Natural England; responsible for promoting the appropriate management of the geological features of the SSSI, and the geological community, who use the site, were keen to see maintenance of the structure abandoned and consequently, the structure being lost to the sea. At the very least, geoconservationists called for the appropriate planning process to be followed in order to determine whether or not the structure should be permitted given the importance of the geological features that were being obscured. However, instead of applying for planning permission, some residents decided to launch a legal challenge as to whether the designation of the site as an SSSI was legitimate. The assumption being that if it could be shown that the designation was not legitimate, the need to protect it for its geological features would 'disappear' thus removing any objections to consenting the retention and maintenance of the coastal protection structure that had been built.

4.13.3: Conservation outcome

After legal hearings in the High Court (2008) and the Court of Appeal (2009) it was confirmed that the designation of the Pakefield to Easton Bavents SSSI was lawful. These legal rulings were extremely helpful in endorsing the approach being taken to the designation of nationally important geological features on an eroding coastline as an SSSI. They also provided some additional clarity on issues such as the difference between 'conservation' and 'preservation' and appropriate approaches to defining boundaries for features within designated sites.

In terms of Easton Bavents itself, maintenance of the unconsented coastal protection structure ceased during the period of legal action, and by 2007 most of the structure had been removed by the action of the sea, leaving only some of the larger pieces of building debris behind. Whilst the structure was in place, access to the designated geological features was not possible and the area affected was in unfavourable conservation condition. Had maintenance of the structure been consented the site would have been permanently obscured and inaccessible but once the on-going maintenance ceased, the action of the sea served to return the site to a natural condition where the geological features are available for scientific research and education.

4.13.4: Further information

PROSSER, C.D. 2011. Principles and practice of geoconservation: lessons and case law arising from a legal challenge to site based conservation on an eroding coast in eastern England, UK. Geoheritage, 3, pp 277-287

4.14: Carboniferous Stratotypes

Stream sections (EW) in northern England containing the stratotype sections for several Carboniferous regional Stage boundaries

Conservation issues

- **Managing upland river and stream sections**
- **Working with volunteers**
- **Facilitating field work and research**
- **Managing biodiversity and geodiversity together**

4.14.1: Site description

Upland Northern England is a classic area for the study of middle Carboniferous rocks. Many of the regional reference (stratotype) sections are found in river and stream outcrops across Cumbria, Lancashire, Staffordshire and Yorkshire. They provide a regional reference framework for the study of Carboniferous stratigraphy and associated fossil groups. Early studies focused on goniatite and plant spore assemblages, while in more recent years, the micro-fauna, including foraminifera and conodonts, have become important tools for resolving stratigraphical correlations over long distances.

4.14.2: Challenge and actions taken

Stream and river exposures are largely maintained by natural processes – water flow maintains erosion and exposure either directly, through maintaining scour or indirectly, through removing weathering products accumulating at the base of river cliffs and other exposures. Over time,

Goniatites preserved in argillaceous limestone; the Isohomoceras subglobosum Marine band (Chokierian Regional Stage) at Stonehead Beck, (Stonehead Beck ['Gill Beck']) SSSI, near Cowling, North Yorkshire. ©John Knight reproduced with permission

The stratotype section for the Alportian Regional Stage at Blake Brook (Leek Moors SSSI), near Warslow, Staffordshire – covered in vegetation prior to clearance. ©John Knight reproduced with permission

- and after clearance. ©Patrick J Cossey reproduced with permission

however, the morphology and the behaviour of the stream may change, leading to sediment accumulation and colonisation by vegetation, followed by the further trapping of sediment and vegetation debris concealing exposures. Access routes can also become more difficult or may be completely impeded.

Therefore, in preparation for a 2015 visit of the Sub-commission on Carboniferous Stratigraphy, the Yorkshire Geological Society, working with Natural England and landowners, revisited these classic sections to prepare for the visit. The actions taken included:

- A visit to each section to assess condition and identify any management required for access and to enable viewing and sampling as part of the Sub-commission field visit (and to agree appropriate SSSI consents for management works and sampling).

- Clearance and preparation of sections (and potential access routes). Management works included cutting back of over-hanging vegetation, removal of larger branches and fallen trees and re-excavation of sections which had become silted up, collapsed or degraded.

- In preparation for the field visit, temporary markers were put in place at key reference levels.

- Throughout care was taken to ensure that works did not disturb upland nesting birds (another important element of these upland sites) and that cleared vegetation and excavated material did not further hinder or block stream flow.

Members of the Sub-commission on Carboniferous Stratigraphy inspecting the stratotype of the Yeadonian Regional Stage at Orchard Common (Leek Moors SSSI), Derbyshire. ©Patrick J Cossey reproduced with permission

4.14.3: Conservation outcome

Upland stream sections are largely maintained through natural processes, nevertheless, they can change and deteriorate over time. As a consequence, for planned field visits and research, reconnaissance and pre-visit management is important. The collaborative approach combining the labour of the volunteers with the expert knowledge of the Yorkshire Geological Society (working with conservation agency (Natural England) and landowners, where necessary), enabled the successful clearance and re-excavation of critical reference sections which were successfully viewed and sampled as part of the subsequent international field visit. Management was sensitive to the upland nesting birds and care was taken to avoid any impact on stream flows (ensuring continued maintenance of stream habits and geological sections). These sites remain in good condition and will require only minimal management for future field visits and research.

4.14.4: Further information

KNIGHT, J & LARWOOD, J, 2016. Re-discovering the Carboniferous of Northern England, Earth Heritage, 46, 17-18.

4.15: Studley Wood

A stream section (EW) in the New Forest SSSI, Hampshire

Conservation issues

- **The impacts of the modification of a stream course on the geological interest**
- **A rare case of conflicting objectives for biological and geological features**

4.15.1: Site description

Studley Wood Geological Conservation Review (GCR) site lies in the north western part of the New Forest SSSI and provides exposures of the Middle Eocene Studley Wood Member of the Selsey Sand Formation and the Elmore Member of the Barton Formation in the banks and bed of the Latchmore Brook. The site is the stratotype of the Studley Wood Member, and this member, as well as the overlying succession, is also the source of some of the most diverse molluscan assemblages of this age known from northwest Europe.

As with a number of other streams in the New Forest, the meandering course of Latchmore Gutter was modified and straightened during the late 19th century in order to improve the grazing within its catchment by draining the mire on the valley floor. As a consequence of the straightening of the Latchmore Brook, the stream has cut a deep channel penetrating un-leached sediments that are now exposed in the lower banks and bed of the stream. It is only because of the 19th century drainage scheme that the interest features are exposed in the stream, and although fossiliferous Eocene strata may underlie much of the New Forest, leaching to a depth of several metres below the ground surface means that these horizons are rarely seen.

4.15.2: Challenge and actions taken

Until the early 2000s, the Studley Wood GCR site consisted of a deeply incised stream in which the location and condition of exposures varied from time to time depending largely upon recent stream activity. The site was otherwise largely undisturbed.

Southern England, and the New Forest in particular, contains nearly 75% of the valley mire habitat of northwest Europe. Modifications to streams during the late 19th century drained large areas of valley mire. As a consequence, parts of the New Forest SSSI and Special Area of Conservation (SAC) that Latchmore Brook lies within are in unfavourable condition in relation to the biological interest features.

Upper stretch of Latchmore Brook in 2006 showing its gully-like nature with slumped and poached banks containing exposures of leached gravels sands and silts. ©Natural England/Dave Evans.

During 2006, consideration was given to a strategy that might achieve favourable condition for the biological interest. The key to the restoration of these habitats is to raise the water table so that it is at or close to ground level on the valley floors for most of the year. This could only be achieved by raising the bed of the Latchmore Brook to a height close to its level prior to the original drainage operations and would require the infilling of the gully created by the present course of the stream. The impact of this on the GCR site is to bury it and render it inaccessible, as, once the water table has risen, any excavation in order to reach the interest features would be likely to need permanent pumping while it was open.

By 2010, a funding stream was available to carry out this strategy, and the Forestry Commission (FC) completed the first phase of the project to re-mire the upper reaches of the Latchmore Brook Catchment (mostly outside of the boundary of Studley Wood GCR site). Prior to the commencement of the work FC commissioned a survey of the GCR site in order to assess the distribution of the interest features across the site. The commission was later extended to provide advice on the later, downstream phases of the restoration. That part of the GCR site affected by the restoration was surveyed and sampled prior to infilling, and on the advice from the commissioned study, it was decided, because of the predicted negative impacts on the remainder of the GCR site, to monitor the behaviour of the Latchmore Book for the next five years.

During this period, gullying and bank erosion in the unrestored stretch of Latchmore Brook continued unabated, whilst the block placed at the downstream end of the restored stretch of the brook acted as a

waterfall, creating a splash-pool which was slowly undermining the block with the potential to destabilise the restoration above this point. In 2015 the Forestry Commission decided to apply for planning permission to restore the downstream course of Latchmore Brook by infilling the stream bed and side drains, whilst returning it to its original meanders. In recognition that the plan would result in the Studley Wood GCR site becoming inaccessible, the Environmental Statement (ES) proposed that a comprehensive rescue that included detailed surveys and systematic collection of material be carried out as mitigation for this impact.

The proposals set out in the planning application proved to be controversial and attracted objections from a number of statutory consultees, as well as representations from the public who objected to the scheme in relation to a range of issues that included its impact on Studley Wood GCR site. The application was refused in 2016, largely on the grounds of the impact that the construction work would have on the residential amenities of local people, and also because of the divergence of views on the ecological benefits of the scheme.

Latchmore Brook within Studley Wood. The stream is deeply incised with actively failing banks. Patchy exposures of fossiliferous silts occur in the lower parts of the banks and bed of the stream. ©Natural England/ Dave Evans.

4.15.3: Conservation outcome

Cases such as this, where the requirements for the conservation of a biological and geological feature are in conflict with each other are rare, and in general, the needs of the different interests may be compatible, or at least may be accommodated. Where such conflicts do occur, and the unavoidable impact on the geological interest is such that it is effectively lost, it is essential that a comprehensive rescue package is included as part of the scheme. Such a package should facilitate the detailed recording of features as well as the systematic collection and sampling of geological materials.

Upper stretch of Latchmore Brook in October 2010. Stream bed infilled but with a low gradient to meet the block at the start of Studley Wood. ©Natural England/Dave Evans.

4.16: Fenland Network

A network of extensive buried interest (EB) and finite buried interest (FB) sites in Norfolk, Cambridgeshire and Lincolnshire

Conservation issues

- **Conservation of a network of shallow buried interest sites in the Fens where the geological interest is not visible and condition assessment is therefore challenging.**

4.16.1: Network description

A total of six locations (Setchey and Wiggenhall St Germans in Norfolk; Adventurer's Land Guyhirn and Shippea Hill in Cambridgeshire; Cowbit Wash and Horbling Fen in Lincolnshire); form a network of Holocene SSSIs across the Fens (Norfolk, Cambridgeshire and Lincolnshire). They represent different stages of the sea level changes that characterised the Fens during the Holocene (the last 11,500 years) in different parts of the Fenland basin. A network of sites is required because the pre-Holocene landscape of the Fens consisted of several distinct embayments that each differ in their sedimentary history and show some variability in the timing of marine transgressions. The sites are composed of alternating layers of peat and clay termed the Fenland Formation. The clays were deposited under marine or estuarine conditions during and after periods of sea-level rise. The peats were formed during periods when relative sea-level rise was negligible and the embayments were dominated by peat-forming wetlands. Some sites such as Shippea Hill are also rich in Mesolithic archaeology. At a number of sites, radiocarbon dating has been used to constrain the timing of the marine transgressions and regressions, to give an exceptional record of Holocene sea level change and crustal changes in England. The palaeoecological records (e.g. pollen, diatoms) at the sites also given an insight into past environments and sedimentary processes. The dating and palaeoenvironmental evidence allows correlations to be made between sites across the Fenland basin. The sediments are usually accessed by borehole in agricultural fields.

4.16.2: Challenge and actions taken

In practice, it is difficult to assess the condition of Fenland sites by visual means as the geological interest is below the surface of the ground. Fenland sites with peat records are susceptible to changing water levels. If water levels are to fall below the top of the uppermost peat, this could result in drying out and oxidation, which in turn will destroy the palaeoecological record contained in the peat. Applications for consent to vary water levels are therefore scrutinised in detail, and related to the published stratigraphy at the site.

Horbling Fen SSSI Lincolnshire covers an area of 17 hectares in two adjoining fields to the left of the drain. The site records the most landward extension of the Wash at about 3700 BP. ©Natural England/Dave Evans.

Condition assessments have focused on checking that sites remain visually intact, and that access to the sediments is still available via borehole on site. This includes checking that there is no evidence of activities or structures that may impede access to or damage the sediments. These may include the construction of tracks, hardstands and buildings, as well as agricultural practices that may disrupt the sediments such as deep ploughing, tree planting, digging drainage ditches, installation of land-drains or alteration of water levels. In an ideal world, condition assessments would be carried out periodically by borehole inspections of the sediments at these sites, however this is an expensive and invasive process. Instead, academic researchers including Quaternary scientists and archaeologists are encouraged to report on the condition of sites when they conduct fieldwork and sampling, and report any concerns to Natural England.

4.16.3: Conservation outcome

The network of sites across the Fenland basin exist to conserve the nationally important record of sea level change during the Holocene. Although each site is important in its own right, all sites have additional value as part of the wider Fenland network. The condition of the sediments at these sites cannot be monitored directly or regularly as it is too costly, requires complicated logistics, and is in itself invasive. Instead sediment records are assumed to be intact as long as water levels are maintained and the land use does not change significantly. Access to the sediments (usually by borehole) also needs to be maintained. Where consent to conduct fieldwork on these sites is given, Natural England will ask for reports on the condition of the sediments accessed during fieldwork. The approach described here may be applied to a range of similar sites that include such areas as (for example) the Vale of Pickering, North Yorkshire.

4.17: Hylton Castle Cutting SSSI

A road cutting (ER) within Sunderland

Conservation issues

- **Management of scrub on active road cutting**

4.17.1: Site description

Hylton Castle road cutting provides a section through part of the Permian Magnesian Limestone of Sunderland, northeast England. This site is part of a network of rail and road cuttings, and disused quarries across the city of Sunderland that expose different facies of the Permian Zechstein reef. Here part of the reef core is exposed and contains a diverse brachiopod, bivalve, bryozoan and gastropod fossil fauna.

Hylton Castle Cutting SSSI before clearance. ©Natural England/Jonathan Larwood,

4.17.2: Challenge and actions taken

Vegetation in the cutting had been allowed to regenerate, resulting in the concealment of the exposure by a thick cover of scrub that has restricted visibility and impeded physical access. Clearance of the exposure was undertaken by Sunderland City Council. This required the cutting and chipping of scrub and the removal of chippings off-site. Remaining stumps were treated in order to inhibit regrowth. The closure of the road for the duration of the works was also necessary.

4.17.3: Conservation outcome

The reef section is now visible and accessible while scrub re-growth has been limited. The removal of the scrub has significantly reduced shading, providing much improved conditions for the associated Magnesian Limestone flora.

Hylton Castle road cutting during clearance – scrub cutting, chipping and road lane closure. ©Ruth Oatway reproduced with permission

4.18: Brewin's Canal Section SSSI

Disused canal and minerals wagon-way cutting (ER) in Dudley, West Midlands

Conservation issues

- **Managing vegetation, scree build-up, and cleaning exposures**
- **Managing geological sites in an urban area**
- **Need for on-going management and working with volunteers**

4.18.1: Site description

Brewin's Canal Section SSSI is located in Dudley, West Midlands and is in the northern part of the large Saltwells Local Nature Reserve (LNR) and NNR. It encompasses an active canal and disused mineral line (that linked the canal to the nearby Doulton's Clay Pit). The LNR and NNR is managed by Dudley Metropolitan Borough Council and the canal side by the Canal and Waterways Trust. Exposures include Silurian sandstones and shales unconformably overlain by Coal Measures conglomerate. Both are transected by a dolerite intrusion. This is a historically important section, examined and illustrated by Sir Roderick Murchison in his pioneering research into the Silurian System.

4.18.2: Challenge and actions taken

These sections suffer progressive degradation through the encroachment of vegetation, and the build-up of scree and soil, particularly obscuring the lower parts of the sequence. Fly tipping is also a problem with relatively easy access from nearby roads. Regular vegetation clearance and

Brewin's Canal, January 2018. Late Silurian Downton Castle Sandstone exposed in the Brewin's Canal section just west of the bridge abutment. These exposures are regularly cleared of vegetation. ©Natural England/ Jonathan Larwood

Wagon-way section, January 2018. During clearance – all terrain vehicle in floor of cutting with exposures of the Upper Whitecliffe Formation and the base of the Downton Castle Sandstone Formation exposed in the cutting. ©Dudley Metropolitan Borough/Graham Worton reproduced with permission

cleaning of rock faces is needed, as well as on-going monitoring for fly tipping and occasional removal of rubbish.

In 2001 volunteers from the Black Country Geological Society (BCGS) cleared the canal sections of vegetation using narrow boats to remove material from the site and access the northern side of the canal. The BCGS has since maintained the sections with regular vegetation clearance and using brushes to clean rock exposures.

In 2017, the wardens from the Saltwells LNR, working with a group of business volunteers, re-exposed the wagon-way section. Scree and soil that had accumulated in the floor of the cutting was excavated and redistributed well away from any exposures. The vegetation was cut-back. A portable high pressure water wash was used to remove the remaining soil from the face in order to slow the rate of recolonization by vegetation. The high pressure wash was transported to site on an All Terrain Vehicle (ATV) with a portable generator and water supply. Fly tipping remains an occasional problem which is monitored and addressed by the wardens. The restriction of access from the adjacent road is being considered in order reduce the frequency of future fly tipping.

4.18.3: Conservation outcome

The clearance of vegetation and scree, as well as the cleaning of the rock faces (using brushes and high pressure sprays) maintains access to these classic geological sections. They now form part of a wider network of ‘Geosites’ as part of the Black Country UNESCO Global Geopark, and are the subject of new, on-site interpretation which is currently in development.

High pressure wash – Wagon-way, January 2018. High pressure water lance being used to remove soil and recalcitrant vegetation from exposures. ©Dudley Metropolitan Borough/ Graham Worton reproduced with permission

Wagon-way, January 2018. Faces cleared of scree, vegetation and soil adhering to face and in cracks. ©Natural England/Jonathan Larwood

4.19: Roade Cutting SSSI

An active railway cutting (ER) in Northamptonshire

Conservation issues

- **The effects of health and safety issues on the management of steep exposures in close proximity to rail and road routes**
- **Managing the impacts of stabilisation works on exposures in an active railway cutting**
- **Use and potential value record and rescue**

4.19.1: Site description

Roade Cutting SSSI lies on the main West Coast Line just north of the village of Roade in Northamptonshire. The site consists of about 1700 m of railway cutting with steep faces rising to about 10 m either side of the track bed, and rising a further 10 m at a lower angle. The cutting originally exposed the whole of the Middle Jurassic, Great Oolite Group, which here rests unconformably on the Northampton Sand Formation and includes in ascending order the Rutland, Blisworth Limestone, Blisworth Clay and Cornbrash formations. The Cornbrash Formation is present under the low angle batter at the top of the cutting, whilst the Blisworth Limestone Formation is exposed in the steep faces at the southern end of the cutting. The Rutland Formation is present behind the brickwork at the northern end of the cutting, and until the mid-1970s small exposures of the Rutland Formation remained in this area. The extensive exposures of the Blisworth Limestone differ from the succession exposed at the nearby Blisworth Rectory Farm Quarry SSSI and indicate the presence of breaks in the succession at several levels at Roade. The extensive nature of the exposures at Roade also facilitate the study of individual sedimentary units over a substantial distance.

4.19.2: Challenge and actions taken

During 2006, an inspection of the cutting revealed that rock fragments were spalling from the faces, while signs of more extensive instability were observed. This clearly constituted a threat to the safe operation of the strategically important rail route. It was clear that stabilisation works would be necessary in order to secure the future safe running of the railway. In response to this situation, Network Rail's contractors proposed a phased programme of mitigation involving the installation of rock-fall netting on the faces of the cutting. Netting often has a severe impact on

Roade Cutting SSSI prior to de-vegetating and the installation of rock-fall netting. The interest features are partially obscured by vegetation and talus. ©Natural England/Dave Evans

the visibility of the interest features and can promote vegetation growth on the exposure, as once the netting is in place, it is difficult to remove vegetation growing on the face. Having looked at alternative techniques including rock bolting that would have less impact on the geological interest, it was clear that in terms of safety, the netting of the faces was the only viable solution, and the exposures at the southern end of the SSSI would be no longer visible. Although it proved possible to retain a narrow strip free of netting close to one of the road bridges, this was not sufficiently adequate to demonstrate the lateral variation of the Blisworth Limestone Formation. Network Rail contracted the British Geological Survey (BGS) to fully record the exposures prior to them being netted. After the faces had been de-vegetated, the surfaces were recorded in detail using ground-based LiDAR, facilitating the development of a three-dimensional model of the cutting. The site was then surveyed at night during track possessions, with a series of logs being taken in order to record lateral changes in the succession. Fossils were systematically collected from the logged sections and deposited with the BGS collections at Keyworth. Finally BGS published two reports on the recording that took place during the two phases of netting installation. A short article was also published in the journal Geology Today.

4.19.3: Conservation outcome

Given that this is a busy main line, the interest features have never been particularly accessible, although they were visible from the several bridges that cross the cutting. The covering over of much of the exposure in netting means that there is no longer any chance of studying this succession at this location – even at a distance. This is an ongoing problem, particularly with railway cuttings, but to a lesser extent with road cuttings as well. In such cases the only remaining option may be to record and rescue. This was the case with Roade Cutting, although it provided the first opportunity to study this part of the site in detail for 150 years. In addition, the BGS reports provide a detailed record of the lateral variation of sediments in the Blisworth Limestone Formation along an extensive exposure. The same study also lead to the proposal of the Roade Member for the basal unit of the Blisworth Limestone – the stratotype being located at Roade Cutting.

4.19.4: Further information

BARRON, A.J.M. & WOODS, M A. 2010a. The geology of strata exposed in Roade railway cutting, Northamptonshire: engineering phase Priority 3 sections and overall assessment. British Geological Survey Commissioned Report, OR/10/039.

BARRON, A.J.M. & WOODS, M A. 2010b. The geology of strata exposed in Roade railway cutting, Northamptonshire: engineering phases Priority 1 and 2. British Geological Survey Commissioned Report, CR/06/012.

WOODS, M., BARRON, M., HOBBS, P. & BOON, D. 2007. Rock, Rail and Roade—uncovering a geological treasure. Geology Today, 23, 227-230.

4.20: Hornchurch Cutting SSSI

A railway cutting (ER) in Greater London

Conservation issues

- **Conservation of an important Ice Age sequence adjacent to a railway line with limited access.**

4.20.1: Site description

Hornchurch Cutting SSSI reveals unique sections through a succession of Pleistocene sediments. These consist of river gravels overlying a till deposit – sediments lain down by a glacier - known at this site as the Hornchurch Till. The Hornchurch Till is important as it marks the maximum southerly extent of the Anglian ice sheet (an ice sheet that covered much of Britain around 450,000 years ago during a major glacial episode – the Anglian glaciation). The sediments at this site also provide evidence for the past history of the River Thames. The Anglian glaciation resulted in large ice sheets covering much of Britain and reaching North London. This ice blocked the old route of the Thames, and thus forced the river southwards into the modern course that we see today. Hornchurch is significant as it not only records the southernmost extent of the Anglian ice sheet but is also the first site to provide evidence of the Thames' new course. The site was discovered by the geologist T.V. Holmes, who led a Geologists' Association field trip to the excavations taking place for the construction of the Romford to Upminster railway in March 1892. His field trip report states that many Jurassic fossils were collected from the boulder clay, including a vertebra of a plesiosaur. The site was re-excavated in 1983 and over three metres of Hornchurch Till was revealed. The site is adjacent to St Andrew's Park in Hornchurch and forms the south side of the railway cutting.

A view along the railway cutting at Hornchurch after the vegetation clearance had taken place. ©Natural England/Emily Dresner

The trench, first excavated in 1983, which was re-excavated in 2010. This has now been covered with geotextile and backfilled so it can be re-opened in future (with permission of Network Rail and Natural England). ©Natural England/Emily Dresner

4.20.2: Challenge and actions taken

The location of the site next to a live railway line makes access for management and scientific research difficult. In recent years the site had become overgrown, which obscured the important geology. During 2010 a joint project between Natural England and Network Rail took place to restore the site. Following collaboration between Natural England, geological specialists and Network Rail's local maintenance team in Romford, extensive clearance work revealed the cutting face, enabling geologists to survey the sediments along the 300m length of the site. The restoration work also helped to re-locate the trench excavated in

1983. Once the clearance and field work had concluded, a geotextile was used to protect the 1983 trench before it was backfilled. Natural England and Network Rail are agreeing a long term management plan to ensure the site is maintained and kept free of heavy vegetation. This means that the geology of Hornchurch Cutting will be conserved and available for study by future geologists.

Following the clearance and excavation work, Hornchurch Railway Cutting SSSI featured in a the Channel 4/ National Geographic International series 'Birth of Britain', presented by Tony Robinson, in the episode on Ice, and first shown on Channel 4 in January 2011.

4.20.3: Conservation outcome

Hornchurch Cutting SSSI is a challenging site to access and manage due to its position in the cutting of a live railway line. Collaboration between Network Rail, Natural England and scientific specialists resulted in the site being cleared of vegetation which enabled access for study. A long term management plan for the site will ensure that it is kept free of heavy vegetation in the future, which should, allow access for study in the future when permitted by Network Rail.

Scientific experts, Network Rail and Natural England staff with Tony Robinson during the filming of Birth of Britain for Channel 4/National Geographic International. ©Natural England/Emily Dresner

4.21: Farley Dingle SSSI

A road cutting (ER) in Shropshire

Conservation issues

- **Degradation of exposures as a result of vegetation encroachment and scree build-up.**
- **Early consultation in the planning process to convert a potential threat to a site into a site enhancement opportunity.**

4.21.1: Site description

Farley Dingle SSSI is a road cutting located on the A4169 near Much Wenlock, Shropshire. The site is designated as an SSSI for exposures of the Silurian (Wenlock Series) Farley Member of the Coalbrookdale Formation in the type Wenlock area. It shows the transition from the underlying mudstones of the Coalbrookdale Formation, to thinly bedded limestones with subordinate mudstones that reflect the shallowing of the sea prior to the development of the reef tract that characterises the upper part of the Much Wenlock Limestone Formation of Wenlock Edge.

4.21.2: Challenge and actions taken

The site was originally a disused railway cutting. As is typical for many disused railway cuttings, the exposures of this classic section were largely concealed by vegetation and fallen rock debris. In 1992, it was proposed that the A4169 be re-routed and widened. This had the potential to destroy the exposures within the SSSI, leading to the loss of the interest features. Following consultation with English Nature at an early stage in the planning process, Shropshire County Council agreed to take advantage of the new route and to leave a permanent exposure in the new road cutting. A new steep section was subsequently created, greatly improving the exposure and enhancing the SSSI. The steepness of the section inhibits growth of new scrub and helps to maintain the exposure. The soft and friable nature of the mudstones means that the face is prone to weathering, with rock fragments spalling off, creating a build-up of scree at its base. This presented a significant hazard because of the proximity of the road. In order to counteract this problem, the face was obliquely benched during the creation of the new section. This provided scientific benefits by allowing easier access to higher levels of the face. A crash barrier has been erected to further reduce the safety risk. This serves the dual purpose of helping to prevent rock debris from falling onto the road and also protects visitors to the site from traffic.

General view of Farley Dingle road cutting during construction. © Natural England/Jonathan Larwood

4.21.3: Conservation outcome

Through negotiation with the local planning authority, the new roadside section has significantly enhanced the Farley Dingle SSSI. It cannot be overstated that the opportunity to discuss the retention of a geological section at an early stage within the planning process was crucial to the success of the project. This allowed time to agree on a design for the steep section with platform access, which could be accommodated within the new road design. During the intervening 24 years, there has been some vegetation growth on the cutting face, whilst weathering has opened up joints and loosened blocks. In 2016, Shropshire County Council carried out major maintenance on the cutting, clearing the exposure of vegetation and descaling loose rock. The cutting now looks much as it did when the new cutting was first created.

4.21.3: Further information

LARWOOD, J. G. & MARKHAM, D. 1995. Roads and geological conservation: a discussion document. Peterborough: English Nature.

Farley Dingle SSSI in 1992, consisting of a largely overgrown disused railway cutting. ©Natural England/Dave Evans

4.22: Birling Gap

A static (IS), active (IA) geomorphological and finite mineral (FM) site in East Sussex

Conservation issues

- **Conservation of active and static geomorphological sites threatened by coastal protection schemes**

4.22.1: Site description

Birling Gap forms an important part of the Seaford to Beachy Head SSSI in East Sussex on the coast of southern England. There are two designated geomorphological interests at Birling Gap; one active and one static. The active geomorphological interest consists of a cliff-beach-shore platform system developed on chalk, stretching between Seaford and Beachy Head. The static geomorphological interest consists of cliff exposures at Birling Gap, which demonstrate one of the best examples of a complete cross-section through a dry valley fill in Great Britain. The dry valley fill is limited in extent, making it a finite mineral (FM) site also. The chalk in the area of the dry valley has experienced intense periglacial weathering which has had an impact on the strength and stability of the cliff sections. With coastal chalk habitats in Great Britain making up about 57% of European coastal chalk habitats, the biological importance of the chalk foreshore is also significant.

4.22.2: Challenge and actions taken

The cliffs at Birling Gap are eroding rapidly, posing an ongoing risk to a group of cottages on the cliff top. The dry valley feature and the underlying chalk are very strongly weathered, so they are even more susceptible to erosion than the surrounding cliffs. Consequently, erosion rates in the area of the dry valley are high. In an attempt to protect the cottages at Birling Gap, local residents put forward proposals to build a rock revetment at the foot of the dry valley cliff section to reduce coastal erosion.

The proposed coastal protection scheme would, however, have impacted on the SSSI in a number of ways. Firstly it would have obscured the dry valley and prevented the ongoing erosion required to maintain the cliff exposure of the feature. The revetment would be potentially damaging to the active process interest by disrupting the natural coastal processes operating within the wider area, which is largely free from coastal protection. Furthermore, the rock revetment would reduce the aesthetic quality of the site and its construction would result in damage to the wave-cut platform and its associated wildlife. The longer term impact upon the natural evolution of the coastal sections was unclear.

General view of Birling Gap showing the cross section in the cliff of the valley fill forming the floor of the dry valley with the chalk cliffs of the Seven Sisters in the distance. ©Natural England/ Mick Murphy

English Nature, backed by many letters of support from the geological community and local schools, argued that the proposed scheme would have an adverse effect on the geomorphological interest of the site and its educational use. The National Trust and the Sussex Downs Conservation Board also opposed the scheme, expressing concern about the visual impacts on this spectacular and naturally evolving stretch of coastline.

English Nature, the National Trust and the Sussex Downs Conservation Board opposed the planning application and the case was heard at a public inquiry in 2000. As a result of the public inquiry, the application for a coastal protection scheme was refused by the Secretary of State for the Environment.

The Planning Inspector made the following points:

- Development proposals affecting SSSIs must be subject to special scrutiny;
- The importance of a scientific feature stems from its intrinsic merit and is not reduced if it has not been fully investigated;
- It is society, through legislation, rather than scientists alone, that place a value on protected sites such as SSSIs.

The application argued that a refusal of planning permission would be contrary to certain articles of the Human Rights Act, stating that it was the applicants right to protect their property. The Secretary of State concluded that failure of the State to exercise its powers to protect a person's home from environmental blight may constitute an interference under the European Convention on Human Rights. However, he went on to say that these are qualified rights which require a balance to be struck between the individual's rights and the interests of the wider community.

A further issue relating to this case involved redefining the exact location of the SSSI boundary. Since the site was first designated as a SSSI, coastal erosion at Birling Gap has resulted in the cliffs eroding back to a position landward of the original SSSI boundary (as depicted on the notification documents). The site was re-designated with a new boundary, prior to the public inquiry to ensure that the interest features in the cliff remained within the SSSI boundary. This is a potential issue on many coastal sites, where erosion may result in the cliff-line eroding inland of the original SSSI boundary.

At present the crest of the cliff at Birling Gap is several metres from the visitor centre. The National Trust are making plans for a new visitor centre; therefore demonstrating adaptive management on a coastal site with high erosion rates.

4.22.3: Conservation outcome

The geomorphological interest at Birling Gap is secured for the foreseeable future. Balancing the need to protect property from eroding cliffs with the need to conserve the coastline and natural processes is always a challenging issue.

4.22.4: Further information

PROSSER. C. 2001. Spectacular coastline saved. Earth Heritage, 16, 4-5.

Coastguard cottages at Birling Gap in 2016. Part of this terrace of houses has been demolished because of its proximity to the cliff edge. ©Natural England/Dave Evans

4.23: Wiveton Downs (Blakeney Esker)

A static fossil geomorphological (IS) esker in North Norfolk

Conservation issues

- **Conservation of a static geomorphological site which has been affected by past quarrying activities**
- **Interpreting classic landforms for visitors, local communities and educational groups**

4.23.1: Site description

Blakeney Esker is a classic landform of outstanding importance for teaching, research and demonstration purposes. Lying within Wiveton Downs SSSI, it is arguably the best-developed esker in southern England, with a sinuous ridge extending over a distance of some 3.5 km from Blakeney to Glandford. The esker is composed of sands and gravels which were deposited in channels, cut through chalk-rich till. The origin of the esker has been the subject of much scientific debate and research over the years, and this has only recently been resolved. In this undulating landscape of North Norfolk, the overall morphology of the

Gorse burning at Blakeney Esker as part of a heathland restoration project. ©Natural England/Mick Murphy

esker is particularly clear, in the form of a sharp ridge form between 40 – 170m wide and up to 20m high. The internal sedimentary structures are visible in several former gravel pits.

Evidence points to a subglacial origin for the esker, as flowing water cut into the till before the gravels were deposited and no collapse structures have been found that would suggest an englacial origin. Wiveton Downs is part of a suite of landforms comprising, in addition to the esker, a till plain, various kames, kame terraces, outwash plains and a tunnel valley. It is unusual to find such a wide range of features, most of which have exposures, in such close proximity in lowland southern England. The esker was probably formed close to the edge of an ice sheet approximately 450,000 years ago. Norfolk County Council has purchased part of the Blakeney Esker at Wiveton Downs, and opened it to the general public as a local nature reserve. As well as use by the local community, the site is also visited regularly by educational groups. Interpretation has been developed on site and online to raise awareness of the esker and explain its significance to visitors.

4.23.2: Challenge and actions taken

Eskers are potentially valuable sources of sand and gravel, and material has inevitably been removed by quarrying. As eskers are important landforms, quarrying can have a significant negative impact upon their integrity. Quarrying can, however, play an important role in creating exposures, aiding understanding of the internal composition, structure and formation of an esker.

Between World War II and the early 1990's, a number of pits were developed along Blakeney Esker for sand and gravel extraction. All of these pits are now disused. A negative effect of this quarrying has been to fragment the classic landform feature. In addition, many of the sand and gravel channel deposits within the landform have been removed by quarrying. There has also been some backfilling of pits along with grading of pit faces and landscaping, and there are now areas of made ground. This has reduced the availability and visibility of sediments for study.

However, the quarrying did create temporary exposures through the sand and gravel channels. These were used by researchers to investigate the origin of the esker while quarrying activities were taking place. Without the quarrying, it would not have been possible to access these exposures, which have been vital for the scientific understanding of the esker. Negotiations with the operator led to a small sand and gravel deposit from one of the workings being retained as a conservation section. In addition, worked-out hollows, which represent parts of

Small area of exposed gravels at Blakeney Esker. These small exposures allow researchers to determine the internal structure of the esker. ©Natural England/Eleanor Brown

The ‘Blakeney Esker explored’ interpretation panel, designed by British Geological Survey, Queen Mary University of London and Norfolk County Council, and funded by the Aggregates Levy Sustainability Fund (administered by English Nature). ©Natural England/Eleanor Brown

Blakeney Esker Explored

Formation of Blakeney Esker

Norfolk has experienced cycles of cold and warm climates over the last two and a half million years. These range from times when the Norfolk landscape would have been covered by a ice-sheet like that on Greenland today, to intervals with climate much warmer than now. Blakeney Esker relates to one of the cold glacial periods. Where you are now, you would have been beneath glacier ice! A river would be flowing under your feet, through a tunnel beneath the glacier. As the climate warmed, the glacier reduced in size and retreated to the north, where the sea is now, and the sands and gravels carried by the water were left behind. A ridge of sand and gravel that forms in this way is known as an esker.

Glaciers covered much of Norfolk. The esker marks the route of a river flowing in a tunnel beneath the glacier.

The ice melted away leaving sand and gravel that had been carried by the river, in the shape of a long ridge.

The Blakeney Esker is the best example of an esker in England. However, eskers are forming today as glaciers retreat in cold environments such as Iceland.

Quarrying at Blakeney Esker

The esker was used as a local source of sand and gravel from World War II to the late 1980s. Permission was initially granted for quarrying at the Wiveton Downs Pit, now a Local Nature Reserve. This remained the largest pit, but the number of pits grew. You can find four other major disused quarry sites if you take a walk on the bridlepath along the esker, towards the coast. The sand and gravel from the esker would have been used locally for a variety of purposes, such as building materials and in the construction of local WWII airfields. All of the useful sand and gravel has now been removed.

Quarrying at the Wiveton Downs Pit during the 1980s.

Scientists benefited from this quarrying as it allowed them to see beneath the land surface. It has helped them to understand the way the esker formed and learn more about Norfolk's geological history.

The site has been designated a Geological Site of Special Scientific Interest and is within the North Norfolk Coast Area of Outstanding Natural Beauty, meaning activities at the site are protected.

Wildlife at the site

Many of the plants you see at Blakeney esker have colonised since the quarrying stopped. Norfolk County Council, the site's owners, have undertaken work to control vegetation at the site. This includes vegetation cutting and sheep grazing, along with occasional fires and intense rabbit grazing. Grazing acts as a natural lawnmower, without it the site would become scrubby woodland and the beautiful springtime bluebells would not grow. The vegetation type found on the esker is called heathland and acid grassland, made up of a collection of plants that require sandy acidic soils with good drainage. This type of soil is provided by the esker.

Vegetation on the esker includes gorse (above left), heather and silver birch. The underlying geology is very different in the surrounding low lying areas, which is generally quite clayey, chalky and not well drained, so different plants grow on and off the esker. Therefore, different animals are attracted to the esker and adjacent low lying ground.

At Blakeney Esker in the summer, look out for sparrowhawks, swallows, yellowhammers (above centre) and meadow brown butterflies (above right). During winter you may be lucky enough to spot great grey shrikes, waxwings and short-eared owls.

Other places to visit

This esker is not the only reminder that glaciers once covered North Norfolk, in fact all of North Norfolk's landscape has been affected by ice. Other landmarks that are related to Norfolk's glacial past are...

Beeston Bump – This large sand and gravel mound (top right) on the eastern edge of Sheringham, was left behind when the surrounding sand and gravel was eroded away.

Cromer Ridge – This long ridge stretching from Overstrand to Thursford marks the maximum extent of a glacier that once covered North Norfolk. This type of glacial feature is called a moraine. Beeston Bump provides a great view of this large ridge (see right).

To find out more

For more information on any of the topics covered by this information board, and for teaching aids on the geodiversity and biodiversity of the site, please visit:

www.bgs.ac.uk/blakeney

To find out more about countryside access in the area, please visit: www.countrysideaccess.norfolk.gov.uk
To find out more about geological conservation, please visit: www.english-nature.org.uk/special/geological

This notice board was funded by English Nature through DEFRA's Aggregates Levy Sustainability Fund (ALSF). The following partners contributed to the project:

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Queen Mary University of London

Norfolk County Council

channels, have been conserved to demonstrate the original morphology of the channels. Quarrying at the SSSI has now ceased and any further extraction is now an Operation Requiring Natural England's Consent.

Management of the geomorphological interest is being undertaken in conjunction with a heathland restoration project which involves clearance of gorse and other scrub. Gorse is also removed from the base of palaeochannels to improve their visibility. An interpretation board was installed in 2004 to explain the importance of the geomorphological features to the general public. Following this, an Aggregates Levy Sustainability Fund project was carried out by the British Geological Survey, Queen Mary University of London and Norfolk County Council in 2005-6 to raise community awareness of the landform and its links with biodiversity, and also provide educational resources for local secondary schools. Community engagement and feedback from local schools helped shape the interpretive and educational materials produced, which included a further interpretation panel.

4.23.3: Conservation outcome

Negotiations with the mineral operator led to research being undertaken during the working life of a quarry operation and conservation of features which would have otherwise been destroyed. Through the purchase of part of the site by Norfolk County Council and the SSSI designation, the integrity of the remaining landform has been secured. New on site and virtual interpretation and educational resources are ensuring that the origins and importance of this classic site are explained and communicated to visitors, educational groups and the local community.

4.23.4: Further information

GALE. S.J. & HOARE, P.G. (2007) The Blakeney esker. In CANDY, I., LEE, J.R. and HARRISON, A.M. (eds) The Quaternary of Northern East Anglia – Field Guide. Quaternary Research Association, London. 204 - 222

GRAY, J. M. 1992. The Blakeney Esker, Norfolk: conservation and restoration. In: STEVENS, C., *et al.*, eds. Conserving our Landscape, 82-86. Peterborough: English Nature.

HARRISON, A.M. & LEE, J.R. (2007) Blakeney esker – an exercise in public awareness. In CANDY, I., LEE, J.R. & HARRISON, A.M. (eds) The Quaternary of Northern East Anglia – Field Guide. Quaternary Research Association, London. 223 – 230.

4.24: Hubbard's Hill SSSI

A static (fossil) geomorphological (IS) site in Kent

Conservation issues

- **A static, fossil geomorphological site with subtle features, managed by liaising with the landowner to ensure land use is compatible with conservation**

4.24.1: Site description

This is an important locality for a sequence of Quaternary periglacial sediments and landforms. The earliest and most extensive of the periglacial deposits at Hubbard's Hill SSSI probably predate the last glaciation. They are now highly dissected but their former extent and volume imply considerable periglacial erosion of the Lower Greensand escarpment. The youngest deposits form a series of prominent solifluction (soil flow due to freeze-thaw activity) lobes between 2 – 4 m thick, overlying a fossil soil and a lower solifluction sheet. The fossil soil has a radiocarbon age of 12,500 BP, so the uppermost solifluction lobes must have formed during a cold snap called the Younger Dryas stadial at the end of the last glaciation. This site contains some of the largest and best preserved solifluction lobes in lowland England, making Hubbard's Hill a particularly important locality for the study of the periglacial processes affecting southern England during the Quaternary.

4.24.2: Challenge and actions taken

The features at Hubbard's Hill are sensitive as they were formed under climatic conditions that are no longer present and the landforms are subtle and easily damaged by incompatible land use. The lobe features are only just stable and in wet conditions they can reactivate. The site

A view across the site looking east which shows the solifluction lobe as a small rise in the centre right of the photograph (arrow). ©Natural England/Eleanor Brown

Looking west showing Lobe F, the location of scientific surveys including boreholes, trial pits, sampling and radiocarbon dating. The revised route for off road motorbikes was designed to completely avoid this lobe. The bare soil on the front of the lobe indicates that there has been recent movement, probably following a period of heavy rain. ©Natural England/ Eleanor Brown

has been under pasture land, which is suitable for conservation. Grazing keeps down the vegetation but as long as stocking levels are not too high, the landforms are visible and the sediments are accessible. This maintains the site in favourable condition.

A few years ago, the landowner applied for SSSI consent to hold regular off road motorbike events. The sloping and undulating topography of the site combined with nearby woodland and field tracks makes it very attractive for this activity. However, the site is subject to 'operations requiring Natural England's consent' (ORNEC) for

- Construction, removal or destruction of roads, tracks, walls, fences, hardstands, banks, ditches or other earthworks, or the laying, maintenance or removal of pipelines and cables, above or below ground.
- Erection of permanent or temporary structures, or the undertaking of engineering works, including drilling.
- Modification of natural or man-made features, including clearance of boulders, large stones, loose rock, scree or spoil and battering, buttressing, grading or seeding rock-faces, outcrops or cuttings.

To address this, Natural England arranged a site visit with two scientific experts. During the visit, the solifluction lobes were mapped and photographed, and discussions were held on site about the compatibility of the activities proposed with keeping the site in favourable condition. Following the visit, a report was provided by the experts setting out the importance of the site, the locations of the periglacial features and the impact that the proposals would have, along with suggested options for avoiding those impacts. A particular concern was that the off road motorbike route proposed cut across part of solifluction lobe F. This solifluction lobe has been the subject of a number of scientific investigations including trial pits and boreholes, soil tests and radiocarbon

dating. There was therefore a serious concern that allowing motorbikes on this intact lobe would cause erosion and damage, and an alternative route avoiding the lobe would be essential for conservation purposes. Natural England used this evidence gathering and advice to discuss alternatives to the route proposed that avoided the sensitive areas of the site. An amended route was agreed and the SSSI consent given contains a map showing the off road motorbiking route permitted (which must be marked on the ground), the location of the car park and the location of the solifluction lobes which must be avoided. The consent given also states that events must not take place during or after periods of heavy rain, again to avoid damage to the site.

4.24.3: Conservation outcome

Through evidence gathering via a site visit with the relevant scientific experts, and discussions with the landowner, a modified route which avoided sensitive geomorphological features was agreed. This case shows best practice in collecting evidence and negotiating a solution for all concerned. This enabled the proposed activities to be carried out in such a way that they are compatible with ongoing conservation of the sensitive geological features.

4.24.4: Further information

MURTON, J.B. and GILES, D.P. 2016. Chapter 4 Reactivation of Lateglacial periglacial shears, Hubbard's Hill, A21 Sevenoaks By-pass. 48-56. In The Quaternary Periglaciation of Kent. Field Guide. Quaternary Research Association, London.

A field just outside the SSSI to the east, where the fence line has been disturbed by reactivation of the solifluction lobe. ©Natural England/ Eleanor Brown

4.25: Brimham Rocks SSSI

A static geomorphology site (IS) in North Yorkshire

Conservation issues

- **Recreational activities at a geological site**

4.25.1: Site description

Brimham Rocks is an excellent example of the scarp-edge tors that characterize the Millstone Grit of the northern Pennines. It is a classic geomorphological site for sandstone tors and a variety of associated rock weathering forms in Millstone Grit. It is significant for studies of past and present weathering processes and their contribution to landscape evolution, although the precise origin of the tors remains unresolved.

4.25.2: Challenge and actions taken

Brimham Rocks lies within the Nidderdale AONB, close to the eastern edge of the Yorkshire Dales National Park. The site is a major tourist attraction in North Yorkshire. The National Trust manages a substantial portion of the site. There is public access to most of the site, which attracts many walkers and climbers.

The high volume of visitors puts pressure on the integrity of the geological features on the site. In particular, impacts can arise from climbing and bouldering, as well as erosion generated by regular footfall. There have also been minor impacts from petty vandalism.

A circular walking route has been established for Brimham which encourages visitors to follow a route that avoids more sensitive areas, reducing path erosion.

As gritstone is relatively soft, climbing can have impacts on the tors through wear from feet and ropes. In addition, in the case of particularly popular routes, path erosion at the base of the tors may lead to erosion at the foot of the tors. The National Trust manage climbing activity though liaison with local climbing clubs and the British Mountaineering Council. In practice, climbers are encouraged to avoid erosion of the gritstone by ensuring that moving ropes do not come into contact with the rock, or by rigging them with either a non-stretch belay rope or sling and resting them on a pad. The use of mats at the base of climbs is encouraged in

Complex of tors along crest of Millstone Grit scarp at Brimham Rocks showing deeply weathered joints, perched blocks and blocks strewn onto the surrounding slopes. ©Natural England/ Hannah Townley

order to reduce path erosion. The use of wire brushes to clean routes is discouraged.

General advice on minimising the impacts of scrambling, climbing and abseiling to rock faces and exposures can be found in the British Mountaineering Council's Green Guide to the Uplands.

Vandals have toppled one of the tor pinnacles, cracking the outcrop. The toppled pinnacle partially shattered on impact. The gritstone shards were used to scrawl graffiti on the outcrops. Fortunately the graffiti was easily removed, and by clearing away the gritstone shards, the means to produce graffiti was removed and the activity has largely ceased.

Vegetation management is also an issue on the site. Tree growth tends to obscure the geological interest features. The National Trust is shifting the balance of the heathland habitat to one with fewer trees.

4.25.3: Conservation outcome

Despite the pressure that high volumes of visitors could put on the geological exposures at Brimham Rocks SSSI, the integrated approach to managing both numbers of visitors and the range of activities that take place on the site means that the interest features are being appropriately managed. This demonstrates the importance of liaison with local interest groups, as well as the use of interpretation to help reduce visitor pressure on particularly sensitive parts of the site.

4.25.3: Further information

- National Trust - Brimham Rocks
- BMC Green Guide to the Uplands

Details of Millstone Grit tor Brimham Rocks ©Natural England/Hannah Townley.

4.26: The Wealden Sandstone SSSIs
Static geomorphological sites (IS) in Sussex and Kent

Conservation issues

- **Vegetation management to maintain a static geomorphological site**
- **Management of climbing activities that may damage geomorphological features on the rock surfaces**

4.26.1: Site description

Rusthall Common SSSI, Kent, High Rocks SSSI, Kent and Wakehurst and Chiddingly Woods SSSI, West Sussex consist of rock exposures that are important sites for Quaternary geomorphology. During the Quaternary, this part of south-east England was not glaciated, but was subjected to periglacial conditions with the development of permafrost as well as the development of gulls (widened joints in bedrock). The sandstones at these sites consist of the Ardingly Sandstone, deposited during the Cretaceous Period. They now exhibit a range of surface features, which are characteristic of weathering in a periglacial environment. These weathering features occur on a range of scales, from small-scale textures on rock surfaces, such as honey-comb weathering, to large-scale features, such as the spectacular Toad Rock at Rusthall Common, which was sculpted by wind erosion. The Ardingly Sandstone forms isolated cliffs and crags across parts of the Weald and are known collectively by climbers as the 'Southern Sandstone'.

4.26.2: Challenge and actions taken

During late Victorian times, Rusthall Common was far more open than at present. Since that time, the rocks have become gradually obscured by trees and scrubby vegetation. This vegetation had a negative impact on the scientific value of the site by obscuring the large-scale geomorphological features.

In order to address this problem, English Nature's Face Lift Programme funded a phased vegetation clearance project on the site, aimed at re-exposing important features. Management work involved thinning trees and carefully removing invasive plant species such as bramble and rhododendron. An interpretation board was also produced to explain the importance of the site to visitors in order to attempt to limit damage to sensitive geomorphological features.

The 'Southern Sandstone' group of sites are used by climbers from across the region because of the scarcity of other natural rock exposures

General view of exposures of the Ardingly Sandstone at Rusthall Rocks SSSI near Tunbridge Wells. ©Natural England/Dave Evans

suitable for climbing in London and south-east England. Climbing is not a generally damaging activity on geological sites, except where the scientific importance lies in the surface features on the rocks, particularly when the rocks are relatively soft. Both of these conditions apply to the rocks at Rusthall Common, High Rocks and at Chiddingly Woods, where the small-scale surface weathering features form part of the notified interest and the sandstones are soft and friable. Damage can occur by rope abrasion and rock bolting as well as by general wear and tear. At Rusthall Common, in order to limit damage to the geomorphological features, one area of face has been set aside for climbers to use. But climbing is discouraged on other parts of the site. In addition, a Code of Conduct for climbers using the 'Southern Sandstone' sites is promoted by climbing organisations. The code of conduct details specific precautions and methods for climbing on soft sandstones in order to conserve the special surface features.

The rocks are also prone to damage by vandalism. Carved graffiti is unsightly and is potentially damaging to small-scale weathering features. Painted graffiti is also potentially damaging and cannot easily be removed because of the likelihood of causing additional damage. Vandalism is difficult to control and even the presence of a sign explaining the scientific importance of the site may have little impact.

4.26.3: Conservation outcome

An extensive programme of vegetation management has greatly enhanced the scientific value of this site. Liaison with the climbing community and the setting aside of a particular area of the site for the use of climbers has been effective in helping manage the impact of climbing activities.

Above: Weathering features on the surfaces of the Ardingly Sandstone at Rusthall Rocks SSSI. Such features may be easily lost through erosion generated by rope friction.©Natural England, Mick Murphy. Below: Example of graffiti at Rusthall Rocks SSSI. This sort of damage is irreparable as it has cut deeply into the surface of the rock.©Natural England/Mick Murphy

4.27: Bradford Kames SSSI
A static geomorphological site (IS) In Northumberland

Conservation issues

- **Managing activities likely to impact on the integrity of an internally complex feature**

4.27.1: Site description

The assemblage of mounds and ridges at Bradford Kames provides an excellent example of the landforms and sediments associated with the decay of the last ice-sheet in northern England.

The Bradford Kames complex is composed of a series of elongate mounds of sand and silt associated with steep sided, locally sinuous, esker-like ridges composed of silt, sand and gravel.

The lack of exposure of the sediments comprising the Bradford Kames complex of landforms means that it has not proved possible to test any of the previous hypotheses regarding their origin. Given the complexity of the site and lack of understanding of the internal structure or relationship between the component features, activities taking place within the site that involve excavation and/or disturbance of the sediments risks the permanent loss of evidence in relation to the origin and development of these features.

4.27.2: Challenge and actions taken

A caravan park is present within the boundaries of Bradford Kames SSSI. This was present prior to the designation of the SSSI. Several schemes have been proposed for the disposal of effluent, as well as the extension of the caravan park. Proposals for the disposal of effluent involve the excavation of wells and trenches for pipes across the site, which would disturb the ground and prevent future access. The extension of the caravan park could require that there is some levelling of ground in order to site new units, again disturbing the glacial sediments. While such schemes might be acceptable, because of the large area impacted by any such scheme and the consequent loss of intact *in situ* sediment, the scheme would required an extensive programme of recording and sampling of excavations, using suitable expertise at an additional cost to the landowner.

So far, such schemes have been refused both because of the extent of loss of *in situ* deposits, but also because the Environment Agency were minded not to provide a discharge consent for the scheme.

Aerial view of Bradford Kames SSSI and surrounding country (SSSI boundary – dashed white line) showing location of caravan site within SSSI. Note also extensive area of woodland at northern end of side. The future management of this woodland may also need to be considered in terms of maintaining the integrity of the features comprising the site. © Google Earth visited 2018. Data SIO, NOAA, US Navy, NGA, GEBCO.

4.27.3: Conservation outcome

Consent for schemes and activities that impact on the integrity of the deposits forming Bradford Kames SSSI have so far been refused, both because of the extent of the impact. This is not to say that consent would be refused for all such schemes, but this would be the case unless proposals contained sufficient mitigation to compensate for impacting the sedimentary record at the site.

4.28: River Dane SSSI

A meandering river (IA) in Cheshire

Conservation issues

- **Responding to damaging activities taking place on a dynamic and rapidly changing river system**

4.28.1: Site description

The River Dane flows through a series of meanders on a broad floodplain constrained to the north and south by river terraces and valley sides. Meanders of the River Dane provide examples of a number of aspects of their development, as well as demonstrating reworking of older terraces into the modern floodplain. The sequence of terraces provide a well-constrained record of the late-Pleistocene to modern development of the river. The river has been the subject of a series of studies of meander morphology and channel change during the past three decades.

4.28.2: Challenge and actions taken

The River Dane SSSI has been the subject of a large number of unconsented activities, almost all of which have arisen from bank protection works attempting to mitigate the effects of the meandering river channel. In addition there have been a number of attempts to develop on the flood plain. In one case, part of the flood plain was levelled in order

Damage to river bank and flood plain of inner side of meander caused by excavation for a track to connect adjacent grazing areas. ©Natural England/ Anna Wetherell

Raising and levelling of land forming part of the River Dane flood plain as a flood defence and for the extension of the caravan site. ©Natural England/Anna Wetherell

to accommodate the construction of lodges, which, since they were immobile, then had to be defended from flooding and the migration of the river banks. All these activities impact on the natural function of the river channels and the flood plain, as well as damaging *in situ* features that provide evidence of how the modern flood plain has evolved.

Since the impacts of these activities on the interest features cannot be mitigated, and may result in permanent damage, the response to such unconsented activities is through enforcement, and where there are proposals through the planning system, by objection to the plans.

To reduce the number of incidents and consequent enforcements on this site, it is necessary to be proactive. This has involved the education of landowners through site visits, as many landowners may be unaware of their responsibilities in relation to the SSSI. Discussions in combination with the Environment Agency have also taken place with local authorities to raise awareness of the impacts of flood plain development, and to identify the locations where such development may not have damaging impacts on the features and function of the flood plain.

4.28.3: Conservation outcome

The outcomes for the conservation of this site may be slow to realise, as it takes time to change the views and actions of people, and it requires education and consistent messages when working with landowners to help understand the SSSI and their responsibilities in relation to its conservation and management. This requires persistence, and may need to be backed by enforcement, planning objection and consenting processes.

4.29: Slade Brook SSSI

An active tufa dam (IA) in the Forest of Dean

Conservation issues

- **The impacts of quarrying on water chemistry, hydrology and tufa formation**
- **Recreation of active epikarst**
- **The importance of the monitoring of water flow and water chemistry**

4.29.1: Site description

Slade Brook supports a long series of tufa dams, associated plunge pools and connecting stream sections that result from the complex physical and chemical processes within the stream and its hinterland.

Slade Brook rises in woodland on the Carboniferous Limestone in the Forest of Dean, flowing for two kilometres to the River Wye. Rainwater enriched in calcium carbonate from percolating down joints and sinkholes in the Carboniferous Limestone of the surrounding catchment area, on re-emerging at numerous springs along the Slade Brook, precipitates calcium carbonate as carbon dioxide is exsolved from the water. Twigs and branches falling into the stream, combined with the growth of algae and mosses, assist in the deposition process and formation of the dam structures through slowing the flow of water and photosynthesis, promoting the removal of carbon dioxide.

Actively forming tufa dams are rare features, and their processes of formation and maintenance are poorly understood. However, they hold the key to understanding the origins of fossil tufa dams and hold great potential for improving our current understanding of these features.

4.29.2: Challenge and actions taken

While factors that include humidity and the presence of vegetation debris are important for promoting the precipitation of the tufa, the key factors are the concentration of calcium bicarbonate in the water and the rate of flow of the stream. These are both determined by the hydrology of the catchment. Dye tracing had demonstrated that there was a hydrological connection between the nearby operational Stowe Quarry and Slade Brook. The effect of quarrying in many karstic areas is to remove the active epikarst - that part of the karst that is most active in terms of the dissolution of limestone and the charging of ground water with calcium carbonate. Thus the presence of active quarries and their extension may affect the hydrological regime in general, but in particular may significantly

Confluence of channels in Slade Brook showing the development of tufa dams and pools at a variety of scales. Fallen leaves may provide sites for tufa precipitation and if left undisturbed, may become incorporated in the dams. ©Natural England/ Dave Evans

change the water chemistry through the reduction of the area of epikarst present. In this particular case, the reduction in the area of epikarst would have lowered the concentration of calcium bicarbonate, directly affecting the ability of the stream to precipitate calcium carbonate in the form of tufa.

In order to mitigate the effects that may arise from the loss of epikarst, the restoration of the quarry includes a plan for the recreation of active epikarst by introducing a layer of granulated limestone to the quarry floors and regenerating soil in order to promote the active epikarst function.

Monitoring of the stream and springs for flow rates and trends in the chemistry of the water may give warning of changes that could impact on tufa production. Monitoring of the behaviour of the replacement epikarst, combined with the monitoring of the stream will in time (years to decades) provide information on the health of the system, as well as in relation to the impacts from quarrying.

4.29.3: Conservation outcome

The combination of the recreation of epikarst to replace that lost to quarrying, combined with the monitoring of the functioning of the replacement epikarst and the flow and water chemistry of the springs and streams may maintain the conditions under which tufa is precipitated in Slade Brook.

Slade Brook is a pioneering example of the recreation of active epikarst and the monitoring regimes associated with quarrying and water quality. The outcome of this work will contribute to a better understanding of the impacts of quarrying on other ground water fed systems and the potential for mitigation, as well as understanding the potential effects of removing ‘dry layers’ in systems feeding alkali fens.

Cascade of tufa dams and pools in Slade Brook. ©Natural England/Dave Evans

4.30: North Dock Tufa GCR Site and LGS

An active process geomorphology (IA) site in Sunderland

Conservation issues

- **Managing an actively forming tufa cascade during and after carrying a major development**

4.30.1: Site description

The North Dock Tufa is an actively forming cascade tufa which is large and spectacular. Plant material is actively incorporated into the tufa, with stalactites and 'cave' pearls forming underneath the overhanging cascade. The tufa is around 6 metres in height, 5 metres across, 2 metres in depth and is estimated to weigh 80 tonnes.

The cascade was found behind some old wooden huts built close to the former North Dock boundary wall, constructed against an ancient cliff of Permian age carbonate sedimentary rocks. The North Dock was opened in 1837, which gives a maximum age for the initiation of tufa formation.

4.30.2: Challenge and actions taken

The tufa deposit was discovered in 1992 during the redevelopment of Sunderland Marina. Upon its discovery, geologists at Sunderland University and Sunderland Museum were contacted and they assessed it as of at least regional importance and if possible should be conserved.

The tufa is now located behind the Marine Activities Centre. The design of the building was specifically modified to conserve the tufa, leaving it open to the elements within an enclosed courtyard. Works were completed to help stabilise the tufa: two concrete pillars were erected to support the tufa and prevent its collapse in the future; and boreholes were drilled horizontally and steel rods emplaced in the holes to anchor the tufa body to prevent it coming away from the wall. A small pool and drain have been constructed in front of the cascade to take away the excess water. A viewing platform with stepped access and lighting have also been installed. At the same time loose rock and core samples were removed and placed in the museum for future research.

The tufa is periodically inspected to make sure it is still stable and that the supports have not deteriorated. The site is also maintained by ensuring the pool remains free of leaves and rubbish, clearing some vegetation from on and around the tufa itself and checking that the drain has not been blocked by tufa!

The tufa has subsequently been designated as a LGS and as a GCR site.

The tufa cascade discovered during the redevelopment of Sunderland Marina – now conserved as a living tufa within the development. ©Natural England/Jonathan Larwood

4.30.3: Conservation outcome

Co-operation between the developer, the planning authority and local geologists has allowed the conservation of this important tufa site. It has a secure future and remains accessible for education and research.

4.31: Pagham Harbour SSSI

An active process geomorphological site (IA) in West Sussex

Conservation issues

- **Challenges arising when seeking to maintain the free functioning of coastal processes associated with a mobile and evolving active geomorphological feature**
- **The potential impact of management interventions on the special scientific interest of active process geomorphological features**

4.31.1: Site description

Pagham Harbour SSSI is a key site for coastal geomorphology, being important both as a classic shingle spit landform and for the links that have been demonstrated between the coastal near shore and offshore forms and sediments. The shingle spit system comprises a series of sub-parallel ridges and recurves, marking different phases of extension and frontal accretion. Shingle reaches the beach via the intertidal zone, and the so-called 'Pagham delta' and the behaviour of the double spit system and delta are intimately linked with water and sediment circulation around the Selsey peninsula. In addition to the geomorphological interest, the subject of this case study, part of the site is important as a rich source of London Clay plant fossils. The SSSI as a whole also includes a range of coastal habitats and is internationally important for wintering wildfowl and waders as well as various communities of plants and invertebrates.

4.31.2: Challenge and actions taken

The spits lie across the mouth of Pagham Harbour and have continually evolved since at least the 18th Century, with the location of the entrance to the harbour changing position regularly over the last 200 years. In 2003, after a period of relative stability since the 1960s, the south-western Church Norton spit began to accrete rapidly in a north-easterly direction and by the end of 2015 it had extended over 1km in the space of 12 years. This extension of the spit resulted in the harbour entrance being deflected through a channel running in a north-easterly direction parallel to the coastline. Continued accretion at the tip led to the flow of the channel being directed onto the coastline itself, resulting in increased rates of erosion directly in front of a number of beachside properties. As a consequence, a rock revetment was constructed in front of these properties in 2013 in order to protect them from erosion. Some local residents also initiated a campaign for the accreting spit to be artificially breached in line with the old harbour mouth in order to divert the flow of the channel away from their properties and in doing so to alleviate the short-term risk of erosion.

Showing the north-easterly extension of the spit in 2013 and the area of increased risk of erosion in from of the houses at the tip of the spit. Plans to artificially breach the spit at the point directly seaward of the harbour entrance posed a potential threat to both the spit itself and the coastal processes forming and shaping it. ©Google Earth, visited 2016. Image Landsat / Copernicus.

Given that the conservation objective for an active process geomorphological feature, such as the spit at Pagham Harbour, is to allow coastal processes to continue to operate and the coastline to evolve naturally, a man-made breach of the spit would be expected to have a negative impact on the condition of the feature. This is especially so, given that an artificial breach in a currently dynamic feature may 'heal' or continue to move location, unless it is held in place through use of some form of 'hard' engineering structure. In short, artificially breaching the spit could be expected to have two impacts on the feature, with the physical cutting of the breach damaging the geomorphological features that make up the spit and the repositioning of the channel altering the future evolution of the spit system.

4.31.3: Conservation outcome

In spring 2016, ongoing coastal evolution unexpectedly resulted in a natural breach of the spit occurring just east of the old harbour mouth, about 250 meters from the proposed artificial breach. This reduced the flow in the channel adjacent to the coast that was causing the increased rates of erosion which were of concern to local residents. This natural change has removed the short-term threat to the beachside properties and both the geomorphological feature of the spit, and the processes shaping it, remain in favourable conservation condition. The now detached section of the breached spit has attached to the down drift coast, increasing the flood and erosion protection to this section of beach. There is still, however, a demand from some local residents for an artificial breach to be created in order to establish a 'stable' coastline. A planning application to do just this was granted by the local planning authority (December 2016) but was not implemented, as the spit had

breached naturally the spit has since accreted and concerns remain regarding flooding and coastal erosion a further planning application has been submitted that can be expected to have a negative impact on the geomorphological features and coastal processes of special interest at Pagham Harbour SSSI.

4.31.4: Further information

Video of Pagham Harbour Spit evolution from March 2003 to February 2021 (YouTube)

DORNBUSCH, U. 2020. Rapid growth and break-up of a 'dormant' shingle spit across the tidal inlet of Pagham Harbour, southeast England. In: GUILLOU, S. (Ed.) Estuaries and Coastal Zones in Times of Global Change: Proceedings of ICEC-2018. Springer Nature, 443-465.

Pagham Harbour spit 2020 with spit naturally breached. The flood delta now facing seaward, and the distal (now separated) part of the spit has accreted to the main strand with a lagoon formed in front of the area that was earlier subjected to scour within the flood delta. ©Google Earth visited 2020. Image ©CNES / Airbus

4.32: Fairy Holes Cave SSSI

A cave (IC) site in Weardale, County Durham

Conservation issues

- **Securing underground access to a cave during development**

4.32.1: Site description

Fairy Holes Cave has developed as a single vadose streamway which follows the shallow dip within an 18 m thick band of the Great Limestone of the Alston Block. The stream follows a system of two joints throughout its 3.2 km length. It is the longest single stream cave in Britain and shows almost perfect geological control of its development. It contains thick layers of coarse sands that contain degraded mineralised sediment coatings. These are deposited and re-worked by regular flood events and form a mineral coating which has preserved a band of rugose corals in the Great Limestone which otherwise would have been eroded. The cave entrance was, for many years, within a working quarry.

4.32.2: Challenge and actions taken

The cave entrance was first notified as a SSSI in 1961, even though the area around the cave also had an extant planning permission to quarry limestone. The cave entrance was duly fenced off and preserved, whilst in line with the planning permission, 600 metres of cave passage behind the entrance were completely removed by quarrying.

In 1991 the cave was renotified as a SSSI. The boundary of the site was redrawn to include the whole of the known cave passage and removed the area of destroyed cave. The cave runs parallel to the quarry face and because of its proximity to the face and, since renotification, the quarrying company funded periodic condition surveys to ensure its integrity was maintained. The quarry closed recently and collaboration between Natural England and the quarrying company, Lafarge (now LafargeHolcim) resulted in a protected access to the cave being retained in the development plan. The quarrying company has spent a lot of time and money protecting the cave entrance from the danger of rock fall by installing a 20 m long steel pipe into the entrance and securing both ends with a steel gate and padlock.

LafargeHolcim worked with the Council of Northern Caving Clubs (CNCC) and other experts to draw up a protocol for allowing licensed access for cavers. The agreement came into effect in May 2013 and is administered

The stream passage in Fairy Holes Cave. ©British Cave Research Association/Dave Checkley reproduced with permission

by CNCC. At the time Lafarge was merging with Tarmac, however, the company ensured the agreement succeeded and laid down a template for the future. The quarry site has now been sold and caving access agreement negotiations are underway again with the new owners.

432.3: Conservation outcome

Although, historically, some of the cave has been permanently lost, the remaining cave passage is now secure for the future. A cave conservation plan is in development by CNCC and scientific monitoring has begun. The secure gate on the entrance means that scientific instruments can be left *in situ* year round in safety. It is an ideal location for cave science.

4.33: Pen Park Hole SSSI
A cave (IC) in Bristol

Conservation issues

- **Cave conservation in an urban environment, involving threat of development**

4.33.1: Site description

Pen Park Hole is a nationally important site. It is the largest and best example of a dendritic hydrothermal cave system in Britain. It contains abundant evidence of hydrothermal dissolution and mineralisation by thermal groundwater rising up along a steeply inclined fault within limestones of Carboniferous age. The cave passage morphology, along with the presence of a thick coating of dog-tooth calcite crystals with dispersed galena, indicate that the cave was formed by ascending thermal waters rather than descending streams, more typical of other caves. The cave is of significant historic interest and was the site of the World's first published survey of a natural cave (Shaw 1979). Pen Park Hole also supports an important community of invertebrate and crustacean species.

4.33.2: Challenge and actions taken

Pen Park Hole is located at the edge of Southmead in north Bristol. The cave lies beneath a small public park owned by Bristol City Council and a development site. It is surrounded by housing and Filton Golf Course. With a main chamber measuring approximately 65 m deep and 60 m across, cave passages at Pen Park Hole are, in some places, just 1.7 m beneath the ground surface. The entrance to the cave is protected by a locked steel lid, with access arrangements controlled by the University of Bristol Spelaeological Society, the Wessex Cave Club and the Bristol Exploration Club.

Although the cave has been known of for many hundreds of years, having first been explored in 1669 (Shaw 1979), it was partially filled and made inaccessible for many years due to concerns around safety. During the 1950s it became necessary to locate the system accurately so that building work could be safely carried out in the area. A resistivity survey was undertaken to try to locate the cave passages and an entrance was dug and opened by members of the local caving clubs. During the following three years the cave was surveyed and geological and biological studies were carried out. The cave was sealed once more in 1961, and was not re-opened until 1993, when a concrete access tube and lockable steel lid were installed.

Intergrown crystals of dogtooth spar (calcite) developed from either wall of a vein in Pen Park Hole. ©Natural England/Chris Westcott

In 2013, a planning application was submitted to build a small number of houses and a supermarket on disused land above and adjacent to the cave. This led to further work in order to obtain accurate location data for the cave passages and determine their depth beneath the surface. Following a campaign by local people that emphasised the dangers of building over the cave passages, the land above the cave was designated as open space by Bristol City Council and the planning application withdrawn.

A second planning application was submitted in 2014, with the footprint of the buildings much reduced and further away from the cave passages. Following consultation with Natural England and local caving groups, the proposal was amended to make sure all buildings were kept as far as possible from the underlying cave passages. The developer also worked with engineers to design a reinforced concrete slab to be installed on the land over the cave passages at the southern edge of the development site, to ensure the safety of people accessing the site and to maintain the integrity of the cave.

4.33.3: Conservation outcome

Pen Park Hole has fascinated people for hundreds of years. Now that the importance of the site has been recognised through its designation as a SSSI, it is possible to ensure that the site is a material consideration in any planning proposals, and that planning conditions can be established in relation to proposals. An important and fragile site, it will remain protected for future generations to study and enjoy.

4.33.4: Further information

- This University of Bristol Spelaeological Society hosted website has more information and images.

View of main chamber of Pen Park Hole. ©Steve Sharp reproduced with permission

4.34: Yorkshire Dales caves and karst

A series of upland sites important for their cave (IC) and karst (IK) interest features in North Yorkshire

Conservation issues

- **Managing recreational impacts.**

4.34.1: Site description

There are 25 SSSIs which include caves and karst features within the Yorkshire Dales National Park. The area forms one of the best examples in Britain of classic limestone scenery, with its scars, such as those at Gordale and Attermire, and limestone pavements, such as those above Malham Cove and at Ingleborough. Beneath the surface are some of the best known cave systems, including the longest cave system in Britain (the Three Counties System) and one of the largest caverns and the highest unbroken underground waterfall at Gaping Gill.

A classic example of limestone pavement above Malham Cove, Yorkshire has become unnaturally polished by the passage of the boots of visitors and walkers. ©Natural England/Hannah Townley

Goredale Scar, Malham, Yorkshire. The complex of features within the gorge provide evidence contributing to an understanding of the development of the Malham – Gordale complex. ©Natural England/Peter Wakely

4.34.2: Challenge and actions taken

Over nine million people visit the Yorkshire Dales every year. Many visit for outdoor recreation including walking, caving and climbing.

Some of the caves within the national park contain fragile cave decoration (e.g. stalactites, stalagmites and calcite floors), some contain important sediments or minerals and at least three caves contain important Pleistocene faunas; all of which could be easily damaged inadvertently. To help with their conservation, the British Caving Association has worked with the British Cave Research Association and Natural England to develop minimal impact caving guidelines. Currently only two caves have site specific cave conservation plans. These provide detailed information on the geological (and biological) interests, together with prescriptions for the conservation of these features. Cave conservation plans will be produced for other caves in the Dales.

The British Mountaineering Council (BMC) has worked in partnership with The Yorkshire Dales National Park Authority, Natural England and the Royal Society for the Protection of Birds (RSPB) to produce a ‘green guide’ to the Yorkshire Dales. Aimed at climbers and walkers, the guide describes the SSSIs in the area and details the crags and peaks found

within them. It contains good practice advice for people going climbing and walking.

As well as numerous short walks, there are ten long distance trails that cross parts of the Yorkshire Dales including the Pennine Way and the Coast to Coast path. Many people also try to complete the Three Peaks challenge, climbing Ingleborough, Pen-y-Ghent and Whernside. Most of these routes pass by or over important geological sites. Although these sites are relatively robust, some features can be obscured by litter or damaged by the collection of geological specimens.

All visitors to the Yorkshire Dales are asked to follow the Countryside Code which gives good practice advice to visitors to the countryside under the themes respect (considering other people and their property and animals), protect (looking after the natural environment through taking litter home and keeping dogs under effective control) and enjoy (planning ahead and following local advice to help you enjoy your day)

4.34.3: Conservation outcome

Although the Yorkshire Dales attracts many visitors for recreation, there are various conservation codes in place which help to ensure that the cave and karst features are protected from recreational impacts.

4.34.4: Further information

- Minimal Impact Caving Guidelines
- The Countryside Code
- Yorkshire Dales Green Guide

4.35: Cheddar Gorge SSSI

A karst site (IK) in Somerset

Conservation issues

- **Managing a karst landscape for geological and biological interests.**

4.35.1: Site description

Cheddar Gorge, located in the Mendip Hills in Somerset, is Britain's largest and best known limestone gorge. It was formed by fluvial erosion and weathering of the Carboniferous Limestone over a period of about 2 million years. Cheddar Gorge is part of The Cheddar Complex SSSI which is notified for multiple geological and biological interest features. The geological interests include karst, caves, minerals and fossils. The biological interests include a wide range of semi-natural habitats which support several rare plants.

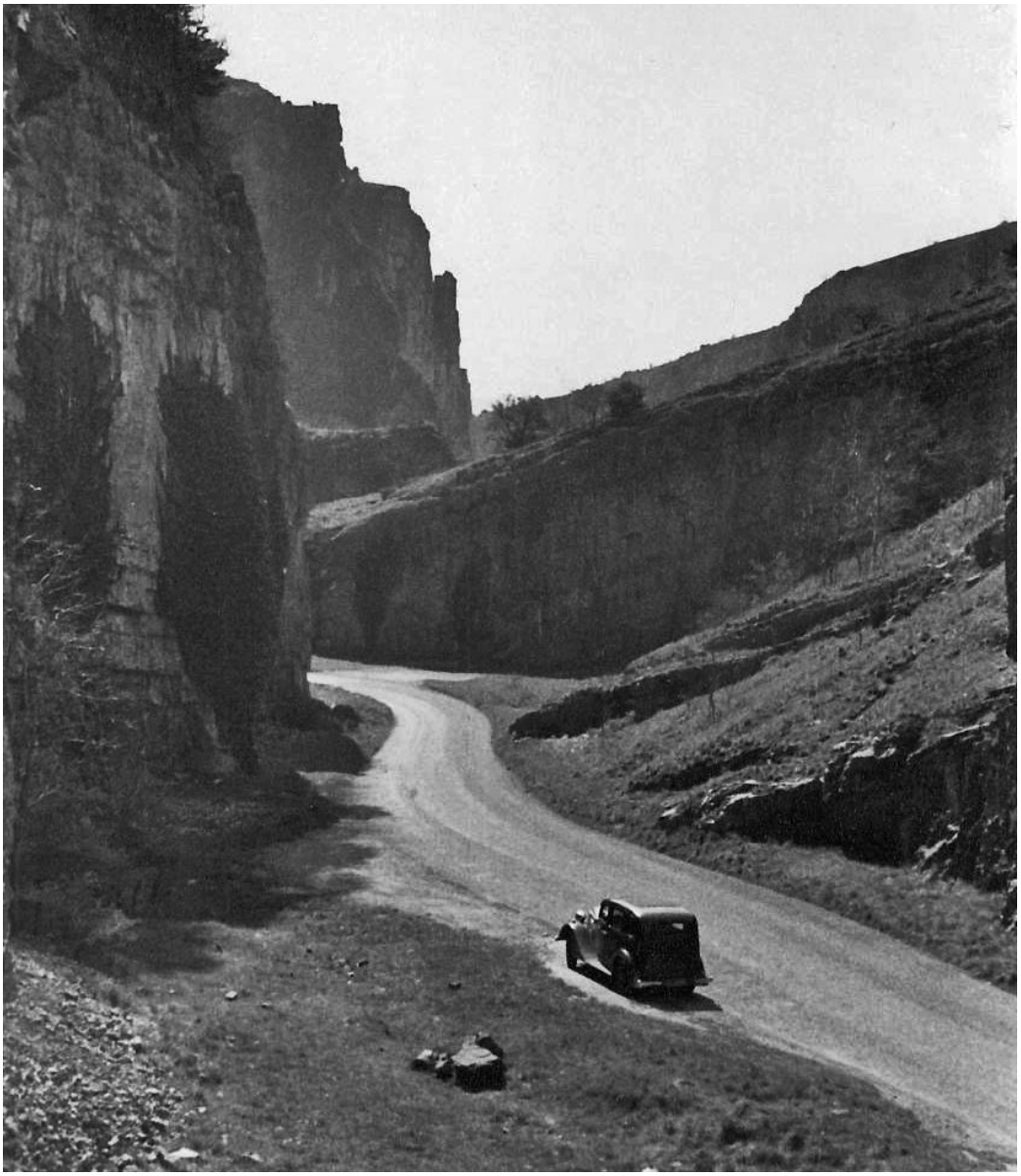
4.35.2: Challenge and actions taken

The site has been subject to a gradual change over many years from a dominantly grassland environment with just a few trees on the steeper cliffs, to a significantly diminished grassland area, with dense scrub and secondary woodland. This has occurred in response to a reduction in grazing in the 1930s and the effects of myxomatosis on rabbit populations in the 1950s. The gorge was losing its rugged, rocky character as the cliffs, screes and slopes became increasingly covered in scrub and woodland, and the karst features were becoming increasingly less visible.

In order to reverse the effects of loss of grassland and the spread of scrub, a major programme of tree and scrub clearance was initiated and grazing was reintroduced to the area. The main driver for this work has been conservation of the biological interests but the karst interest has also benefited indirectly from the work. A gradual improvement to the geological and biological interests has been observed, but the management regime needs to be sustained.

4.35.3: Conservation outcome

The development of a management programme for restoring the grassland habitats has benefited both the biological and geological interest features.



Cheddar Gorge in 1952 with small quantities of vegetation developing on the faces and bedding surfaces. ©Natural England

Cheddar Gorge, 1991: Image taken from location diagonally opposite that taken by W. A. MacFadyen (above), showing the expansion of vegetation cover over nearly 30 years. ©Natural England/Peter Wakely.

4.36: Charnwood, Long Mynd and Joint Mitnor Cave *in situ* finite fossil (FM) resources

Conservation issues

- **Conserving finite fossil resources *in situ***
- **Managing risk from weathering, erosion and vandalism**
- **Access management**
- **Mould and cast techniques in geoconservation**

4.36.1: Site description

Charnwood (Leicestershire), Long Mynd (Shropshire) and Joint Mitnor Cave (Devon) each have finite fossil resources that are managed *in situ*. The Precambrian rocks of the Charnwood and Long Mynd areas include a number of locations where the surfaces of bedding planes exhibit complex Ediacaran trace fossil assemblages. Joint Mitnor Cave retains *in situ* cave sediments containing a diverse large mammal assemblage dating from the Ipswichian interglacial. This forms part of the visitor display.

4.36.2: Challenge and actions taken

There are a number of challenges in managing finite fossil resources *in situ*. These include deterioration through weathering and erosion as well as damage caused by recreational activities, vandalism and theft. The Precambrian Charnwood fossils in more accessible locations do suffer from recreational erosion (scrambling and climbing on rocks), graffiti on bedding planes, and deliberate theft of fossil specimens. The Long Mynd Precambrian fossils have also been subject to illegal fossil collecting, depleting the resource at a number of localities. Joint Mitnor Cave was recently (2016) broken into and several fossil bones stolen from the *in situ* display. To address these challenges a number of management solutions have been adopted:

Managing access: where feasible access to vulnerable and finite fossil localities should be restricted and carefully managed. Though not fool-proof, caves such as Joint Mitnor have secured entrances and controlled access (see also Horn Park NNR (ED and FM)). Where secured access is more difficult to achieve, such as the more publically accessible localities in the Charnwood area, details and publicity over the exact location of sensitive localities is restricted to avoid drawing attention to potentially vulnerable fossils. Signage is also used to discourage scrambling and climbing on rock surfaces where erosion is a concern.

Secure covers: on the Long Mynd, an area which was a particular target for illegal collecting, a secure cage has been constructed, enclosing the

Application of silicone rubber to make the moulds on a steeply dipping bedding plane containing an Ediacaran assemblage in Charnwood. ©Dee Edwards reproduced with permission

fossiliferous bedding planes maintaining the visibility of the feature. The cage can be unlocked to allow direct access to the section. See also the Horn Park NNR (ED and FM) fossil bed cover.

Vandalism: graffiti incised into bedding plane surfaces in Charnwood has been a concern for some years and is difficult to repair. The approach taken has been to reduce the overall visibility of graffiti through coloured treatments painted onto the surface with a close match to the surrounding rock colour. Whilst this does not prevent vandalism it reduces the visibility of graffiti improving the overall quality of outcrop and diminishing the temptation for further vandalism.

Recording through photography, moulding and casting: where there is a risk of erosion, vandalism and possible theft it is important to have a detailed photographic record of key outcrops (so any changes can be readily seen). *In situ* moulds have also enabled accurate 3D casts to be made.

Protective 'cage' enclosing bedding planes containing an Ediacaran assemblage on Long Mynd. ©Frank Hay reproduced with permission

Joint Mitnor Cave, Devon – wolf, bear, bison (top photo) and straight tusked elephant replicas (middle photo). ©William Pengelly Cave Studies Trust reproduced with permission

Joint Mitnor Cave, Devon – Fossil bones were stolen from the exhibit showing a partially excavated cave earth. These were replaced by replicas of specimens from Joint Mitnor held by the Natural History Museum (NHM). The original NHM specimens were replicated by 3D scanning and printing, and the replicas were then used to make casts for exhibition in the restored talus cone. ©William Pengelly Cave Studies Trust reproduced with permission

Silicon rubber moulds have been used in Charnwood, Leicestershire. This involved careful cleaning of exposures and the application of layers of silicon rubber which was lifted as a mould once cured. The moulds were then used to manufacture plaster of Paris casts replicating the bedding surface. At its most challenging, moulds were prepared of a steeply dipping bedding plane, approximately 150 m^2 in area. Individual moulds up to 6 m^2 in area were prepared, a small overlap between the areas covered by each mould was included. Square metre casts were prepared from the moulds. The assemblage of casts provide a perfect replica of the *in situ* bedding plane and trace fossils. They can be used to help monitor any changes and damage to the outcrop. They provide a research resource that can be analysed and photographed under controlled conditions (which is often difficult to achieve in the field), and also provide a resource for education initiatives.

At Joint Mitnor Cave 3D replicas were made to replace the stolen vertebrate fossils. Natural History Museum material previously collected from the cave were scanned and the data used to create replicas through 3D printers. Moulds were created from the replicas, followed by the production of gypsum casts, coloured using natural pigments. The casts have now been reinstalled in the cave replacing the stolen fossils. (See also Wadsley Fossil Forest (FB) fossil tree mould and casts).

4.36.3: Conservation outcome

A number of different techniques have been adopted to address the risk of *in situ* deterioration and damage. Managing and controlling access, where feasible, is important including secure gated access on caves, fencing and, where a specific outcrop is threatened, the construction of a secure cover. Caution about publicising sensitive sites is also important. Though it should not be considered as an alternative to *in situ* conservation moulds and casts have provided accurate 3D replicas of a number of 'at risk' sites. If damage occurs the replica still exists. The replica can also be used for research, and educational and interpretation purposes.

4.36.4: Further information

FINCH, A., 2018. Making replicas of stolen fossils at Joint Mitnor Cave, Devon. Earth Heritage, 49, 45-47.

WILLIAMS, D, & EDWARDS, D, 2013. Moulding and cast replication of outcrops: a tool in geoconservation. Proceedings of the Geologists' Association, 124, 648-652.

4.37: Globe Pit SSSI

Finite mineral and fossil site (FM) in Essex

Conservation issues

- **Conservation of a soft sediment site with a very finite resource in an area of high development pressure**

4.37.1: Site description

Globe Pit SSSI is an up-stand of sediment on the margin of a very large disused chalk quarry, situated in Essex on the outskirts of London, close to the M25 Dartford Crossing. The site is important for understanding the Quaternary history of the River Thames. Globe Pit is also known for the occurrence of Palaeolithic human artefacts. Here, the remaining sediments are very restricted in extent and, as a consequence, are being managed as a finite resource.

The adjacent chalk quarry and brick pit was created to serve the local building industry. Globe Pit is located in a highly urbanised area where there is a high demand for housing, and there was strong pressure to develop the site after quarrying ceased. The ensuing development in the pit floor has created several problems for successful conservation of the remaining sediments, which are considered as finite features for conservation purposes.

The southern face which is in close proximity to the housing estate before clearance works. ©Peter Allen reproduced with permission

The southern face after clearance works by GeoEssex. ©Peter Allen reproduced with permission

4.37.2: Challenge and actions taken

At Globe Pit, there are a number of conservation issues. Firstly, the deposits are finite in extent, and are at the feather edge of the Thames river terrace of Corbets Tey Gravel. Secondly, by the 1980s the quarry faces had been cut back to the point where the remaining fossiliferous deposits had been removed. Thirdly, those deposits that remain are unconsolidated and mechanically weak. Fourthly, there is very little space between a housing development on the floor of the disused pit and the former quarry face.

The last situation appears to have occurred as a result of a modification of the development plan, over which there was no consultation with (then) English Nature. Originally, there was sufficient space left between the proposed development and the geological interest in the quarry faces, to allow visual and physical access to the sections of interest. The modified plans allowed properties to be built with gardens encroaching within a few metres of the former quarry face. This has severely restricted access to the geological interest for both study and site management.

As a consequence, the management of Globe Pit presents significant challenges, in particular the maintenance of a clean, stable face in the soft sediments. The existing faces are now overgrown and degraded but re-excavation of fresh faces is not a realistic option because the interest is very limited in extent. Local volunteers from GeoEssex periodically clear scrubby vegetation, particularly in areas of the southern face, to ensure that some access for research and visiting fieldtrips can be maintained. Given the finite nature of the reserve of sediment and the proximity

to houses, exposures are not created unless needed for research or fieldtrips. Material that has been washed down the face or has slipped is now impinging on garden fences, and it will probably become necessary over time to replace them. Removal of the toe of slipped material is not advisable as this acts as a support for the sediment above. The proximity to the properties also increases the likelihood of material such as garden waste being tipped on site. Vegetation is not removed adjacent to the main access point to deter unauthorised access. The remaining reserve of sediment is also very difficult to access for study, because of the steep slopes and the close proximity to houses. The creation of an access route up one of the faces would normally be desirable, but in this case the removal of material to create such a route is very undesirable given the very limited remaining resource. It could also open the site to unauthorised activities including collecting of Palaeolithic material. Due to surrounding development and the position site on the feather edge of the river terrace, there is no potential for expanding the site outside of its current boundary.

The west face which is adjacent to a pocket park. This face is largely Thanet Sand, the Quaternary features are on the top. ©Peter Allen reproduced with permission

4.37.3: Conservation outcome

The remaining geological resource at Globe Pit is very finite. Past quarrying activity and the close proximity of a new development resulted in a less than ideal conservation situation, leaving a challenging site that is difficult to access and manage. Local volunteers are working hard to ensure that some access is maintained by periodically clearing vegetation, but at the same time avoiding the creation of new exposures unless necessary for study. It is important that lessons are learned from the experiences at Globe Pit so that similar problems elsewhere are anticipated and then appropriate steps are taken to avoid these issues at other sites in the future.

4.37.4: Further information

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4.38: Purfleet Chalk Pits SSSI

A finite mineral/finite buried interest site (FM, FB) in Essex

Conservation issues

- **Conservation of a unique and finite deposit in an urban area with high development pressures**

4.38.1: Site description

Purfleet Chalk Pits SSSI consists of undug reserves lying between several disused chalk quarries situated in Essex close to the M25 Dartford Crossing. The site is designated as a SSSI for the occurrence of unconsolidated sediments resting on the Chalk which are important for understanding the Quaternary history of the River Thames. The remaining Quaternary sediments are restricted in extent and, as a consequence, Purfleet is managed as a finite site. The site is also renowned for the occurrence of abundant Palaeolithic human artefacts and is a key site for correlating the Lower Palaeolithic with the Thames Terrace sequence. Fossils are both abundant and well preserved in these sediments. The Thames sediments date from an interglacial approximately 300,000 – 330,000 years ago, which is now termed the Purfleet Interglacial. This interglacial is poorly represented in the geological history of England, making Purfleet a unique site and of international importance.
The remaining Quaternary resource is considered to be finite for conservation purposes.

INQUA visit to Purfleet Chalk Pits during 2019. Professor Danielle Schreve with a macaque finger bone collected from the interglacial sediments exposed in the disused quarry. ©David Bridgland/Durham University reproduced with permission

Access road to warehouses immediately adjacent to the former quarry face. This face has been graded and covered with a geotextile, rendering it inaccessible for future study. ©Natural England/Natalie Bennett

4.38.2: Challenge and actions taken

Purfleet Chalk Pits SSSI has been subjected to severe development pressure since quarry operations ceased, and major industrial developments (warehouse and distribution centres), transport corridors, housing and associated infrastructure have been constructed between the pits and on the former pit floors. The sediments themselves are unconsolidated and therefore prone to collapse, and due to their limited distribution, unnecessary re-excavation or attempts to maintain clear exposures would reduce the volume of remaining resource still further. The siting of an access road to an industrial unit built in the floor of a former chalk pit has caused problems. The road in question is in close proximity to the former pit. During the development of the site, the upper part of the face failed, depositing Quaternary sediments onto the access road. As a consequence the failed part of the face was graded and covered with geotextile to prevent further collapse. This action, necessitated by health and safety concerns, sterilised part of what was already a limited reserve, rendering this part of the SSSI inaccessible for future study. The lesson here is that development and associated infrastructure must be sited beyond a buffer designed to contain any potential collapse of soft sediment faces and provide sufficient working area to access the interest feature for fieldwork and management

activities. The width of the buffer must be informed by an appropriate geotechnical surveys. Generally, a minimum of 10 - 15m between the face and any buildings or associated infrastructure may be required in order to maintain access to the interest features, and increased accordingly to accommodate potential mass movement activity.

Bluelands Quarry is being infilled with inert waste to create land for a mixed use development. The planning permission includes conditions designed to protect and conserve the SSSI. These include a buffer zone between development and the former quarry faces.

The construction of the Channel Tunnel Rail Link led to the loss of part of the site. This was unavoidable, and mitigation/compensation in the form of a rescue and recording scheme was applied along the route within the SSSI. This incorporated an initial phase of test pits to establish the geoarchaeological potential and inform the design a scheme of work to mitigate the impact of construction. A more detailed investigation which involved creating, logging and sampling a series of six large trenches then took place. During the construction phase, large sections were created as the Purfleet cutting was excavated. These were also surveyed.

To ensure that there will be a resource available for future study at Purfleet Chalk Pits SSSI, the site was renotified in 2003, incorporating an additional area of unquarried land (the former Esso sports ground) underlain by similar sediments. This area will act as an undug reserve and can be excavated if the scientific need arises. Since the inclusion of the additional reserve English Nature/Natural England was consulted on a housing development. The applicant was encouraged to include the needs of the SSSI in the design of the surrounding development. Boreholes were drilled across the site and the cores analysed. The results were used to inform the design, avoiding building on the deepest reserves of Thames deposits; assigning this area as part of the greenspace required within the development. In order to avoid placing bunds to provide basking areas for invertebrates on the area above the reserve, the topsoil was lightly furrowed from east to west, creating subtle south facing ridges. A watching brief was carried out during the geotechnical survey and ground works. It involved the inspection and recording of the Quaternary sediments. An interpretive leaflet and toolbox talks were prepared in order to brief construction workers on the nature and importance of the SSSI.

In the former Greenlands Quarry, visited regularly by researchers, students and field trips, a conservation section has been created, and its conservation is incorporated in the management plans for the site. Access to the conservation section is strictly controlled by the operators of the warehouses. This is advantageous as the site is not accessible

except though formal arrangement, so there are no concerns about unconsented collecting of the limited resource.

4.38.3: Conservation outcome

The sediment reserve at Purfleet Chalk Pits is very finite and the sediment mechanically weak, with a tendency to collapse. Developments has generated opportunities and threats to conservation at Purfleet Chalk Pits SSSI. Balancing development and geoconservation has been carried out successfully with the more recent development schemes, however earlier developments had a negative impact on the site and it is important that lessons are learned so that similar problems are anticipated and avoided both here and elsewhere. At Purfleet, the incorporation of a buried reserve has relieved some of the pressure on existing exposures and the ensuing development of this unit of the SSSI provides an example of positive collaboration between the developer, English Nature/Natural England and the planning authority, resulting in a development designed around the conservation requirements of the SSSI.

4.38.4: Further Information

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Dr Peter Allen (on the right) inspecting the groundworks as part of a watching brief of the undug reserve during the development of the Esso Sports Ground at Purfleet Chalk Pits SSSI. ©Natural England/Eleanor Brown

4.39: Ebbor Gorge SSSI and NNR

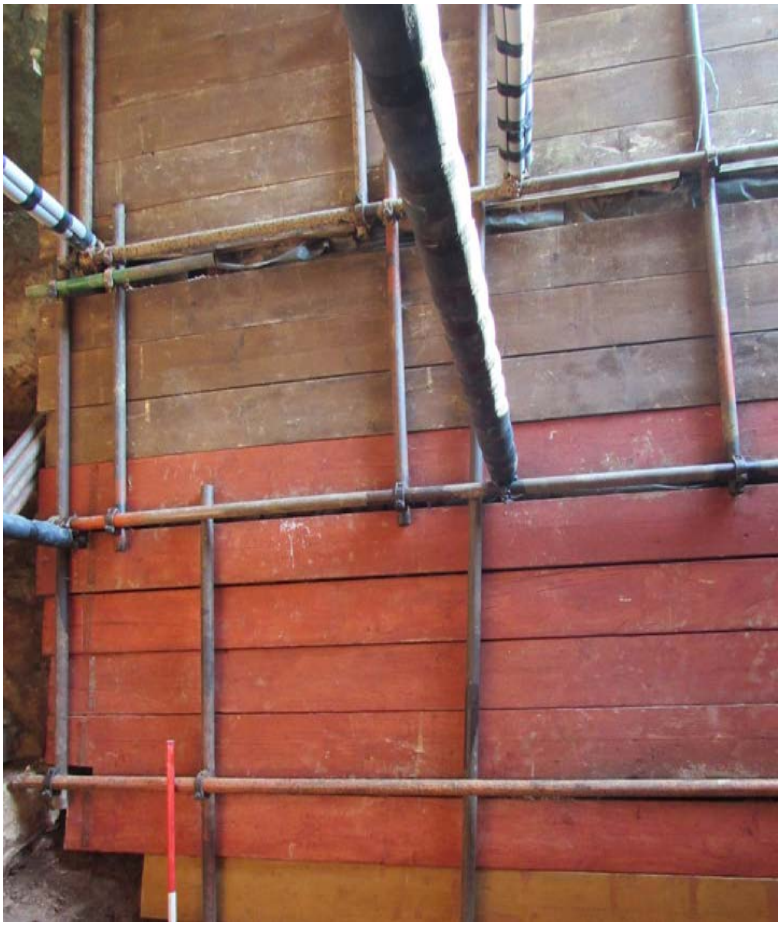
Finite mineral, fossil or other geological (FM) cave sites in Somerset

Conservation issues

- **Conservation of finite cave deposits in the Ebbor Gorge National Nature Reserve in Somerset**

4.39.1: Site description

Ebbor Gorge National Nature Reserve (NNR) lies on the south west facing slope of the Mendip Hills and consists of a steep sided ravine cut into Carboniferous Limestone. A stream issuing to the west of the site runs down the tributary valley of Hope Wood before joining the main gorge. Millstone Grit and Lower Coal Measures form an impermeable floor to this valley. Several caves occur within the Gorge, of which Bridged Pot provides one of the best Late Devensian small-mammal assemblages known from Britain. Most of the deposit remains *in situ*. The fauna includes steppe pika, arctic lemming, Norway lemming, various voles, red deer and reindeer. The small cave/rock shelter at Savory's Hole contains largely undisturbed deposits likely to yield a similar assemblage of Devensian age.



2015: The reserve on the right-hand side of Gully Cave shored up with boarding and scaffolding to its maximum extent maximum extent of shoring in place The left hand side of the cave is undergoing excavation, ©Royal Holloway, University of London/Danielle Schreve reproduced with permission

2017: Beginning excavation and sampling of archive section. ©Royal Holloway, University of London/Danielle Schreve reproduced with permission

Ebbor Gorge NNR is owned by the National Trust and managed by Natural England. The sediments in Gully Cave have revealed a wealth of mammalian fossils from the earliest part of the Holocene (the current interglacial) and the end of the last Ice Age. The limestone cave is a perfect environment for fossil bones to survive in excellent condition. The early Holocene fauna included bones from aurochs, reindeer, water vole and wild cat. The fossil record from a short lived cold spell at the end of the last Ice Age includes reindeer, horse and arctic fox. The sediments that were deposited during the Windermere Interstadial (warmer again) contain red deer, horse and mountain hare. Below these levels there are sediments from the Last Glacial Maximum. These are underlain by older ice age deposits. The cave deposits are very restricted in extent and are therefore managed as a finite resource.

4.39.2: Challenge and actions taken

The wind-throw of a large tree on the edge of the gorge revealed the presence of a cave entrance behind the root plate. Since the other cave sites in the gorge contain well preserved sediments containing Ice Age faunal assemblages, a Quaternary scientist was invited by the NNR wardens to examine the cave entrance and newly revealed cave deposits.

The cave was named Gully Cave. A systematic examination of the cave sediments began in 2006. In agreeing the details of the fieldwork, the National Trust stipulated that 50% of the sediments should remain undug, as a reserve for future work. While this is a desirable objective, it became clear as fieldwork progressed that there were some substantial practical challenges in achieving this. In order to ensure that the reserve of sediment remained intact and did not collapse into the void created by the progressively deepening excavation, the reserve needed to be shored up by scaffolding and boarding. In the longer term, maintenance of the shoring after the excavations had concluded would also be an issue, since in the fullness of time, the wooden boards will decay. An inert material would be required to fill the northern half of the cave to support the remaining intact sediments in the southern half. Given the location of

2017: Red breccia overlain by stalagmite in archive section. Note the rotting boards. © Danielle Schreve, Royal Holloway, University of London reproduced with permission

the site, this would present some financial and logistic challenges – not least whether it is possible to get several tons of non-limestone aggregate (visibly different to the cave deposits) into the cave.

By 2016 the excavation, which had gone down into 3 metres of sediment without any sign of reaching a floor, continued during the summer field season. At this point, the excavation team raised concerns about the long-term sustainability of the undug reserve, as material could be heard collapsing behind the scaffolding and boards. Discussion between the excavators, Natural England specialists and the National Trust concluded that conservation of the undug reserve was becoming both unsustainable and impracticable. The decision was made to rescue and record the undug reserve under scientific conditions, with the appropriate archiving of important finds (e.g. fossils).

It is desirable to keep cave sediments conserved *in situ* so that material is available for future work, including the application of new techniques. However, when *bone fide* scientific access is needed and *in situ* conservation is no longer practicable, then systematic rescue and recording is a valid conservation strategy. Given the situation at Gully Cave, it is now important to survey the caves across the rest of Ebbor Gorge to ascertain the conservation potential of their cave sediments. Intact deposits should then be monitored on a regular basis to ensure they are maintained in favourable condition.

4.39.3: Conservation outcome

In Ebbor Gorge, several caves and rock shelters contain intact cave sediments, which are managed as a finite geological resource. Scientific excavations have taken place in Gully Cave. Had the disposition of the cave sediments been different, it might have been possible to retain an undug reserve. As this has not proved feasible, conservation now consists of rescuing and recording, ensuring that excavations are carried out under controlled scientific conditions with appropriate sampling and archiving of material. Rescue and recording should quite rightly be seen as a conservation strategy of last resort, however, it is an entirely valid conservation approach and is necessary at Gully Cave. This is demonstrated by a recovery rate of fossil material approaching 100% for the 50 tons of material so far put through a half millimetre sieve!

4.39.4: Further information

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4.40: Hope's Nose To Wall's Hill SSSI
Collection problems at a mineral site (FM) in Devon

Conservation issues

- **Irresponsible collecting of minerals at a site with a finite resource**

4.40.1: Site description

Hope's Nose to Wall's Hill SSSI, Torquay, Devon, is renowned for the occurrence of unique and finite gold-bearing carbonate veins within Devonian limestones.

4.40.2: Challenge and actions taken

At Hope's Nose, irresponsible over-collecting of minerals has significantly damaged the geological resource. Intensive and unconsented removal of specimens by the use of power saws has effectively destroyed the geological interest at the site.

In order to try to safeguard the finite mineral resource at Hope's Nose, the site was notified as an SSSI with a special legal condition attached, requiring the written consent of Natural England prior to the collection of specimens. Hope's Nose, however, is an easily accessible site, concealed from public view. Consequently, the requirement to seek permission before undertaking any collecting was difficult to enforce and was ignored by irresponsible collectors. The landowners were powerless as it would be necessary to constantly monitor the site to prevent unauthorised collecting.

Collectors used power saws to remove whole sections of the carbonate veins which hosted the gold, leaving virtually no material of interest exposed. Because the veins die out laterally over a short distance, there is little likelihood of exposing similar material in the future. The damage to the mineral resource at Hope's Nose was extreme, resulting in effective destruction of the interest. At the time of the damage, mainly in the late 1980s and early 1990s, English Nature (now Natural England) had little power to act against third party damage (in contrast to damage inflicted by site owners). The Countryside and Rights of Way (CRoW) Act of 2000 rectifies this by introducing stiff penalties for those third parties found guilty of damaging SSSIs.

Damage caused to mineral vein at Hope's Nose through the unconsented removal of mineral using a rock saw. Note coin for scale to right of hole (end of white line). ©Natural England/Hannah Townley

4.40.3: Conservation outcome

At Hope's Nose, theft has resulted in almost complete destruction of a unique mineral interest. This site demonstrates the problems associated with managing collecting of a highly sought after finite resource in an isolated area. Although specimens from Hope's Nose can still be seen in museums, they can no longer be studied in their original context.

4.40.4: Further information

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4.41: Gipsy Lane Pit SSSI

A restored, disused quarry containing finite mineral (FM) deposits in Leicester.

Conservation issues

- **Conservation management of a dissolving, finite resource, in an urban setting**

4.41.1: Site description

Gipsy Lane Brick Pit SSSI, in north-east Leicester, is a small restored and conserved section of a much larger quarry which extracted clay of the Upper Triassic Mercia Mudstone Group. Here, an unusual deposit of red-bed-style mineralisation of uranium, arsenic, copper, vanadium, nickel and cobalt minerals, as well as organic-rich nodules, is associated with gypsum beds. The site forms part of a nature reserve owned and managed by Leicester City Council.

4.41.2: Challenge and actions taken

In the late 1990s Gipsy Lane Pit SSSI formed part of a large area of waste ground and was often subject to fly-tipping. In addition the site was fairly overgrown and the floor of the quarry often flooded. As part of the development of a new link road and light industry, the SSSI was protected by a metal fence and padlocked to prevent future fly-tipping. The existing fly-tipped rubbish was removed and the quarry floor was flattened and raised using granite chippings to reduce standing water. At the same time an access track was created, to allow future access into the site for both study and maintenance works.

Gipsy Lane Pit SSSI in 2004 prior to any improvement works showing the flooding of the pit floor, fly-tipped rubbish, and talus in front of the face. ©Natural England/Hannah Townley

Reprofiling works to reduce runoff and therefore erosion of the gypsum beds. ©Pendleton Hydro Ltd/Ella Pendleton reproduced with permission

However, a new conservation problem then emerged. Due to the quarrying, the gypsum beds are now at the surface, where they naturally dissolve due to contact with surface water, causing large blocks of the gypsum to break away from the exposure.

Natural England commissioned a drainage study that identified two causes of erosion:

1. A steep embankment to the south of the gypsum exposure, and

2. An area of slumping immediately above the exposure that allowed water to pool and slowly infiltrate, gradually dissolving the gypsum beds below.

Management of this water was needed to conserve the SSSI, as if left unmanaged, the gypsum beds would continue to break down rapidly.

It was decided to undertake re-profiling works in three areas of the site to reduce the erosion of the gypsum beds. The steep slope to the south of the gypsum beds has been re-profiled to reduce the speed of surface run-off and allow water to disperse around the site instead of immediately flowing over the gypsum exposure. The access track, which runs behind the gypsum exposure, has been re-profiled to divert water away from

Cleared faces and raised quarry floor in December 2016. ©Natural England/ Hannah Townley

the gypsum exposure. The area immediately above the gypsum beds exposure has been raised, using material from re-profiling the steep slope, and a composite membrane has been laid down to reduce the infiltration of water from above the exposure.

4.41.3: Conservation outcome

The mineral interest at Gipsy Lane Pit is now secured, with the site protected from illegal dumping and the water now managed to reduce its impact on the gypsum beds. Although the gypsum beds will still dissolve, it will now happen much more slowly, allowing more time for scientific research.

4.42: Force Crag Mine SSSI

An upland site near Keswick in Cumbria with a mine dump (FD) and finite underground (FU) interest features

Conservation issues

- **Conservation management at a disused underground mine**

4.42.1: Site description

Force Crag Mine is an abandoned mine, with its mine dumps, lying at the head of Coledale, about 7 km west of Keswick. The mineralised vein follows the path of a fault trending east-west and cutting across mudstones, siltstones and sandstones of the Early Ordovician Skiddaw Group. The vein has been exploited over a distance of 1 km horizontally, and 350 metres vertically. Force Crag Mine was worked for zinc, lead and barite from 1835 until 1991 and was the last working mine in the Lake District. After abandonment, the site moved into the ownership of the National Trust.

There are two areas of mine working visible on the surface: the High Force workings and the Low Force workings, which are linked underground by the Laporte Incline, a 335 m long tunnel. There are nine levels driven onto the vein, four at Low Force and five at High Force, those at Low Force being associated with large mine dumps.

4.42.2: Challenge and actions taken

The mine was abandoned in 1991, due amongst other reasons, to a collapse in Level Zero, which caused flooding up to Level One, making the lower parts of the mine inaccessible. In the late 1990s work was completed to ensure water could escape from Level One if another collapse occurred. Subsequently there were more movements in the mine spoil and scree which also blocked Level Three.

The mine water from Level One then exited the mine via two pipes. These drained directly into Coledale Beck, a tributary of Newlands Beck, which then drains into Bassenthwaite Lake, part of a Special Area of Conservation. The water exiting the mine has a very high metal content and is particularly polluted with zinc.

To improve the water quality, the Coal Authority in conjunction with the Environment Agency and Newcastle University instigated a project to reduce pollution through an innovative scheme to reduce minewater pollution. The mine water now flows through two ponds and a wetland

Force Crag Mine, Cumbria. Showing the extent of the workings and the pipe taking water from the adit down to Coledale Beck. This is prior to the construction of the settling ponds to remove heavy metals before they can move further downstream and enter Bassenthwaite Lake. © Jim Barton, Force Crag mine buildings. Reproduced under Creative Commons License CC BY-SA 2.0

area, which remove metals from the water. The water treatment scheme is sited on top of the old tailings lagoon, so none of the mineral interest is affected by it. The water treatment scheme opened in 2015 and is estimated to remove around 1 tonne of metals including zinc, lead and cadmium from the water each year, improving water quality downstream. As a by-product of this scheme, it was also proposed to reinstate Level Three to prevent water from entering the mine at this location. This would also allow safe access to part of the mine for suitably qualified researchers.

4.42.3: Conservation outcome

Work to improve the water quality has involved management works aimed at diverting water away from the mine and reducing the chances of flooding in the lower levels. Whilst the underground parts of the mine remain largely inaccessible due to instability, the work to improve water quality has helped to reduce one factor (flooding) that influences the accessibility of the mine.

4.42.4: Further information

- National Trust Borrowdale and Derwent Water

4.43: Skiddaw SSSI

A large upland site with finite mineral (FM), mine dump (FD) and finite underground (FU) interest features in Cumbria

Conservation issues

- **Conserving important finite mineral and mine dump sites while allowing continued appropriate usage**

4.43.1: Site description

The Skiddaw Group SSSI in Cumbria is a large upland site with multiple geological, archaeological and biological interests. The Skiddaw Group SSSI has been designated for 12 separate geological interests. These include a number of mine dumps and mineral sites in the former mining area of the Caldbeck Fells, which is renowned worldwide for the quality and variety of mineral specimens discovered there. This case study concentrates on issues associated with conservation management of the mineralogical interests within the Skiddaw Group SSSI.

4.43.2: Challenge and actions taken

The main threat to the mineral resource within the Skiddaw Group SSSI is over-collecting of specimens. Irresponsible collecting over many years has resulted in significant damage to important parts of the resource. Some important areas have been depleted to the point that little material of mineralogical interest now remains. Additional related damage has been caused to the landscape by collectors digging large trenches and diverting streams. The blocked-off entrances to some disused mines or levels have been forced open, posing a serious hazard. There has also been concern that irresponsible collecting was having a negative impact on the industrial archaeological interest of certain mine dumps.

A large area of the Skiddaw Group SSSI is owned and managed by the Lake District National Park Authority (LDNPA). In January 2000, in order to safeguard the interests at the site, the LDNPA, in consultation with English Nature, the British Geological Survey, the Russell Society and other mineral collecting groups, introduced a policy to control mineral collecting on the Caldbeck Fells. In order to monitor activities on the site to provide better management of its wide range of interests, anybody wishing to remove mineral or rock specimens had to apply to the LDNPA for a permit. The permits were granted annually to collectors for scientific research purposes, who had to provide appropriate justification.

Dale Beck, Caldbeck Fells, Cumbria. The site of numerous disused workings for lead and copper, and one of the target areas for mineral collectors. ©Natural England/ Hannah Townley

However, this system was seen as too restrictive and, in 2004, the mineral collecting permit policy was reviewed and revised. As a first step, English Nature and the LDNPA carried out an assessment of the geological and archaeological value and sensitivity of the mineralogical sites in the Skiddaw Group SSSI.

In March 2005, following extensive consultation with interested parties, the LDNPA introduced a revised permit system. Under the new scheme, the Caldbeck Fells have been divided into colour-coded zones (red, amber and green) which are of varying sensitivity. The idea is to allow some educational and amateur collecting in green and amber zones, while maintaining tight restrictions in more sensitive areas (red zones). All collectors will still require a permit, but the application process has been simplified for green zones, as all collectors are now required to follow a code of conduct which sets out responsible collecting procedure.

This system provides a more flexible approach to granting permits, giving greater access to amateur collectors and educational groups, while protecting the key sensitive areas. LDNPA rangers and voluntary wardens enforce the permit system and a coordinated system of patrols has been set up.

The LDNPA aims to ensure, as far as possible, that the archaeological and geological heritage of the mine workings are both conserved and that legitimate research and recreational activities can continue. As part of this work, the access to underground workings at Carrock Mine (tungsten) was secured in 2011. The LDNPA worked with local mining history groups to

permanently re-open and secure (through a locked gate) the main entrance to the mine, while making safe three other entrances on the hillside.

Although the site is heavily used for recreational and educational activities, including mineral collecting, scope exists for further promotion of the geological and other interests across the site.

4.43.3: Conservation outcome

The revised permit scheme seems to be working well. The management techniques employed by the LDNPA at the Skiddaw Group SSSI provide better protection for the geological and archaeological heritage of the area, safeguard legitimate interests and improve public safety. The permit system appears to be successful in deterring irresponsible and unauthorised collecting.

4.43.4: Further information

- The LDNPA website provides further information on the Caldbeck Fells Minerals and Mineral Collecting Permit Scheme.

Large trench created in the mine dump in Drygill (Cumbria) by mineral collectors diverting the stream. ©Natural England/ Hannah Townley

4.44: Writhlington SSSI, Bath and Northeast Somerset

A mine dump (FD) in Somerset

Conservation issues

- **Recovery and collection of important fossils from a mine dump.**
- **The involvement of geological societies and groups, school parties and the general public in the recovery of scientifically important fossils.**

4.44.1: Site description

Writhlington SSSI forms part of a disused colliery tip located in the village of Lower Writhlington, near Radstock, Somerset. During the reprocessing of the tip in 1984, in order to recover unpicked coal, the Coal Measures mudstones were found to contain a significant assemblage of arthropods, including eurypterids, giant millipedes, arachnids and insects. Some 3,000 tons of this mudstone were set aside as a reserve (Writhlington Geological Nature Reserve) and resource for the future collection of these insect assemblages.

Funding for the creation of the reserve and for interpretation came from a range of sources. In recent years, a regular mechanical turnover of the dump to expose fresh material has been undertaken.

The site is internationally important because of the high diversity and large numbers of Carboniferous fossil insects and other arthropods that have been recovered from the mudstones. The site also yields large numbers of well-preserved fossil plants. Together, the flora and fauna provide evidence that may help to better understand the ecology of late Carboniferous (Pennsylvanian) forests.

4.44.2: Challenge and actions taken

When the reserve was created, the intention was to recover scientifically important fossil material for research purposes. The site is also visited for educational purposes by universities, museums, geological societies and schools under the supervision of geological specialists.

Conditions for using the site also set out measures to manage the way in which the resource is collected. These include an obligation to record all fossil insects found and to make them available for scientific study. Fossil plants are also recorded, but, unless they are of particular interest, specimens may be retained by the collector.

Collecting plant and insect fossils at a Rockwatch event for children in 1994. © English Nature/Colin Prosser

Extensive collecting from the site over a long period of time has inevitably resulted in a decrease in the quality and quantity of fossil material being retrieved. In order to help address this issue, the rock store is regularly turned over in order to expose fresh material. Although last turned over in 2002, fossil arthropods are still being found - albeit in smaller numbers, and a state is now being reached where this activity provides a diminishing return. Inevitably, the time will come when the majority of fossils have been recovered and the resource will be exhausted.

This approach to site management has resulted in maximum scientific and educational gain from what is a strictly finite resource. It has enabled this rare Carboniferous fossil resource to be recovered, studied and curated. Most of the insects recovered from Writhlington are now housed in the City of Bristol Museum and Art Gallery. The experience gained at Writhlington has had the effect of renewing interest in these types of fossil assemblages. As a consequence, new insect fossils have been recovered from other disused tips and opencast workings.

4.44.3: Conservation outcome

As a result of the initiative at Writhlington, a large amount of important fossil material has been collected. Before work began at the site, there were less than 200 specimens of fossil insect known from the whole of the British Carboniferous. Now, more than 1,300 specimens of fossil insects and other arthropods have been recovered from the site, many of them new to science. The understanding of British Upper Carboniferous fossil insect assemblages has been substantially increased by this initiative and it has encouraged the search for such assemblages on Coal Measures sites elsewhere.

4.44.4: Further information

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NATURAL ENGLAND. 2012C. Managing geological specimen collecting: Writhlington Case Study. Natural England Technical Information Note TIN119.

JARZEMBOWSKI, E. A. 1991 . The rock store at Writhlington. Earth Science Conservation, 29, 12-13.

4.45: River South Tyne and Tynebottom Mine SSSI
A mine dump (FD) in Cumbria

Conservation issues

- **Protecting mine dump material from river erosion**

4.45.1: Site description

The mine dumps at Tynebottom mine are part of the River South Tyne and Tynebottom Mine SSSI, which is also of interest for the remains of river terraces (static geomorphology). The mine has extensive mine dumps with an interesting mineral assemblage including erythrite, brocantite, devilline, wroewolfeite, linarite and gypsum. These minerals are important in understanding how the North Pennine ores were formed within the limestone and Whin Sill, and the mine adit and dumps remain an important educational resource.

River South Tyne at Tynebottom Mine, showing the 'log jam' inserted into the river bank, and the eroded bank backfilled with river gravel to form a surface that may become vegetated. © Natural England/Simon Stainer

4.45.2: Challenge and actions taken

The mine dumps at Tynebottom Mine are immediately adjacent to the River South Tyne. Over a number of years the edge of the mine dump has been eroded, over-steepening the river bank and washing mineral material downstream, causing contamination. More recently the access track into the site has also been threatened by river erosion.

To reduce the erosion of mine dump material there were two options. Move the mine dump to another part of the site, or stabilise the river bank. In this case stabilisation of the river bank was seen as the best option as this would also protect the access track into the site.

Hard engineered river bank stabilisation works were considered inappropriate given the designations on the site, so an experimental engineered log jam was created. This involved using locally sourced timber (uprooted trees, stumps and other timber debris) to create a sediment trap against the eroding river bank. Tree stumps and other woody debris were inserted into the river bank horizontally, at a 45º angle to the current. Gravel from the river was used to backfill between the river bank and edge of the log jam. A geogrid membrane was then laid over the top surface to consolidate the barrier, which would allow vegetation to establish over the top surface of the log jam relatively quickly, in order to further stabilise it.

4.45.3: Conservation outcome

The log jam has now been in place since 2013 and initially was very successful in reducing river erosion at this site. Unfortunately the floods associated with Storm Desmond, in December 2015, damaged part of the log jam, although the course of the river has changed slightly too, so hopefully this in combination with the remaining log jam will prevent the site from eroding further.

4.46: Ecton Copper Mines SSSI

An upland site with mine dump (FD) and finite underground (FU) interest features in Staffordshire

Conservation issues

- **Retaining and maintaining access to a disused underground mine**

4.46.1: Site description

Ecton Copper Mines SSSI consists of a complex of mine dumps and mine workings, some of which are connected underground. The mines were worked for copper from the Bronze Age, although the main period of production was from the 16th century, the mine being abandoned late in the 19th Century.

At the surface there are a large number of open and sealed shafts and near-vertical mineralised 'pipe-deposit' entrances along the ridge top, and also a number of levels driven to the workings from the hillside. Many of the mine entrances are associated with mine dumps. There are a number of ruined mine buildings, including a rare late 18th century Boulton and Watt engine house. Several areas of the site are part of a Scheduled Ancient Monument for their archaeological interest.

There are extensive underground workings, many of which are still accessible with varying degrees of ease. The ore deposits were worked down to around 300 m below river level in the 18th and 19th centuries, although everything below the level of the river is now flooded.

4.46.2: Challenge and actions taken

Part of the site is owned and managed by the National Trust, with most of the main mines and the mineral rights owned by the Ecton Mine Educational Trust (EMET), an independent charitable body that promotes the use of the mine and the hill for educational purposes. They are responsible for the routine maintenance of the workings they use for teaching purposes (at present primarily Salts Level). Ecton Hill Field Studies Association (EHFSA) co-ordinate courses here for school and university students, led by volunteer tutors.

Large areas of the Ecton Copper Mines are now flooded and inaccessible, but three of the mine levels are still accessible. Owing to insurance restrictions most visitors are only able to visit Salt's Level, which is dry year-round. However, it is possible for specialist interest groups to explore the mine in greater detail (and depth) but only under strict conditions.

Gated entrance to Ecton Copper Mines. ©Natural England/Hannah Townley

In 2005 a filming project was undertaken by two cavers which illustrates in detail the underground highlights of the Ecton Mines. This specialist film was commissioned by EHFSA as an archive record, as at the time there was uncertainty over future access. Although primarily to record the archaeological interest, the film also shows good examples of the mineralisation, some in areas which can no longer be accessed. Extracts from the film are available on the EHFSA website.

Behind-the-scenes work carried out by EMET, much of it in partnership with other organisations, in particular The National Trust, English Heritage, and Peak District National Park Authority, includes essential maintenance to improve the safety of the mine and the hill, as well as restoration of the important historical features of Ecton. Safety measures such as erecting and maintaining fences, capping shafts and ensuring safe access to the mine and the study centre, is all done by a small number of enthusiastic, experienced, and qualified volunteers.

The G A Cox study centre, named after the previous owner and advocate of the site's use for education and training, converted from one of the old mine buildings, can be used as a meeting place, a lecture room or a laboratory.

4.46.3: Conservation outcome

Although the deeper parts of the mines are inaccessible due to flooding, large areas of mine passage are still accessible and are in use for education, training and research. This is in part down to foresight of the previous owner and the dedication and enthusiasm of a number of volunteers who work to keep the dry areas of the mine safely accessible.

4.46.4: Further information

Find out more about the history of the mine and how to visit the site using the links below:

- National Trust - Ilam Park, Dovedale and the White Peak
- Ecton Mine
- Ecton Hill Field Studies Association

Copper mineralisation in Ecton Copper Mines ©Natural England/Hannah Townley

4.47: Seven Sisters Mine

A finite underground mine (FU) in Dudley

Conservation issues

- **A partnership approach to resolving safety issues related to mine instability while retaining access to a mine**

4.47.1: Site description

Seven Sisters Mine is located within the Wren's Nest SSSI and National Nature Reserve (NNR) in Dudley, West Midlands (see separate case study). The site is owned by Dudley Metropolitan Borough Council and managed by them through agreement with Natural England.

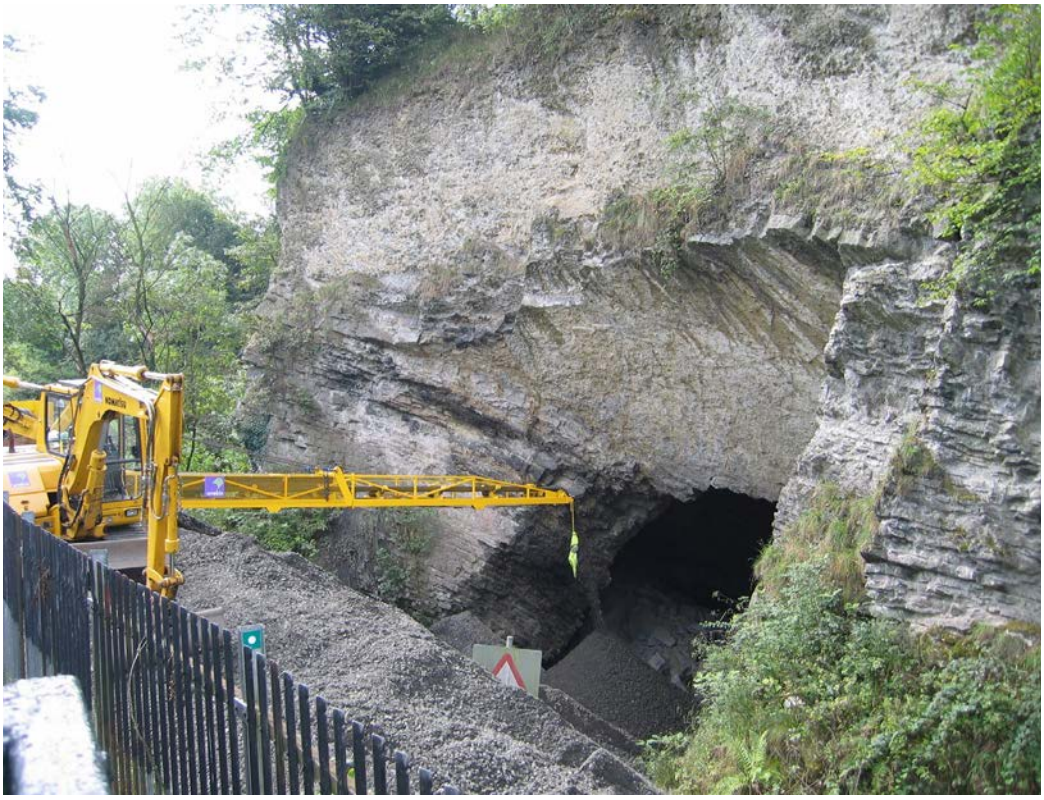
Silurian limestone was quarried and mined at the Wren's Nest from the 18th century until about 1920. The Seven Sisters Mine is a spectacular example of pillar and stall mining. As limestone was extracted from the thickly bedded lower part of the Much Wenlock Limestone, large pillars of the limestone were left supporting the mine roof. At the Seven Sisters, so-called because seven pillars were once visible from the surface, the limestone mine opens onto the surface. Until recently, when the cavern entrances were temporarily filled with aggregate for safety reasons, visitors could see down into the steeply inclined mine with its pillars and stalls.

Seven Sisters Mine is of particular importance as the only remaining accessible limestone mine in the Black Country. In 2004, the Wren's Nest received Scheduled Monument status as a recognition of its importance to industrial archaeology. The site is also of importance as a roosting habitat for bats (protected species) with at least five different species of bat having been recorded.

4.47.2: Challenge and actions taken

The NNR management plan covers routine management of the geological and biological interests of the Wren's Nest and is implemented by Dudley Metropolitan Borough Council. As part of the management plan, significant changes to all features of interest at the Wren's Nest NNR are recorded and reported to Natural England.

In recent years, the main management issues at Seven Sisters Mine have related to the progressive collapse of the mine roof with the associated risk to the public and any ensuing liability matters. Collapse of part of the mine had already resulted in the area around the mine entrance being fenced off with a 2.4 m high, steel palisade fence, and regular mine



Seven Sisters Mine during the infilling process. Aggregate for infill being transferred by conveyor belt into one of the cavern entrances. ©Dudley Metropolitan Borough Council/Graham Worton reproduced with permission

stability inspections taking place to monitor safety. In order to retain a good view of the cavern entrances and supporting limestone pillars, a viewing platform was constructed. Further high-profile collapses within the mine in 2003 pushed scrutiny of the various ongoing management issues to the forefront of the local planning authority's considerations. In this situation, some local planning authorities may have prioritised health and safety at the expense of the scientific and heritage importance of the Seven Sisters Mine. In this case, an engineering solution was sought, which took account of both health and safety and conservation needs at the site. In order to achieve this, a working group of interested parties, including the local planning authority, English Nature, mining engineers, geologists and local historians was set up to try to find a solution.

This partnership approach resulted in an engineering solution being developed which retained the visibility of the mine entrances and limestone pillars which make up the Seven Sisters, ensured access to some caverns for bats, and enabled the caverns to be stabilised by filling them with loose dry aggregate that can be clearly distinguished from the limestone. Although the caverns have been largely filled by the aggregate, the mine entrances and supporting pillars are still visible. Furthermore, this approach means that the future option of completely removing the aggregate from the mine entrances and strengthening the roof with rock bolts remains viable, should funding become available.

The partnership approach to this project, involving engineers, conservation professionals, contractors and the local community in the design stage of the work, has been accepted as a national demonstration project under Construction Excellence and achieved a gold star award, the highest honour. The project has also been awarded full marks on

Looking down on the infilled entrance to Seven Sisters Mine from the viewing platform. ©Natural England/Colin Prosser

the Considerate Constructors Scheme of the Office of the Deputy Prime Minister. This award was based on successful balancing of public safety and environmental issues, together with the adoption of a partnership approach that involved a wide range of stakeholders.

Seven Sisters Mine (update)

Further infill of the caverns underneath the Wren's Nest Hill has been undertaken. This involved pumping in loose sand in order to provide structural integrity to those caverns at risk from collapse. As with the aggregate, the sand can be removed at a later date should the reopening of the caverns ever become feasible.

As part of these works the interiors of the caverns were subjected to a detailed photographic and laser-scanning surveys, recording features on the surfaces. The Step Shaft canal basin, beneath the Wren's Nest, was also accessed and detailed stratigraphic logs were prepared in combination with sampling of the Much Wenlock and Coalbrookedale Formations. This work is now the subject of continuing research. Moulds and cast replicas of selected bedding plane surfaces were prepared prior to the burial of the exposures.

4.47.3: Conservation outcome

The involvement of a wide range of interested parties in designing a solution to conserving the key features of the Seven Sisters Mine, while addressing important public safety issues, has resulted in a successful conservation outcome. Safety issues, which could have resulted in complete loss of the features of this mine, have been addressed in a manner which conserves them in the short term and offers an opportunity to enhance them in the longer term.

4.47.4: Further information

CUTLER, A., OLIVER, P.G. & REID, C.G.R. 2009. Wren's Nest National Nature Reserve Geological Handbook and Field Guide 2nd edition, Dudley Metropolitan Council and Natural England. 30pp

PROSSER, C.D. & LARWOOD, J.G. 2008. Conservation at the cutting edge: the history of geoconservation on the Wren's Nest National Nature Reserve, Dudley, England. From: BUREK, C.V. and PROSSER, C.D., (eds) The History of Geoconservation. Geological Society of London, Special Publications, 300, 217-235.

4.48: Alderley Edge SSSI

A finite underground mine (FU) in Cheshire

Conservation issues

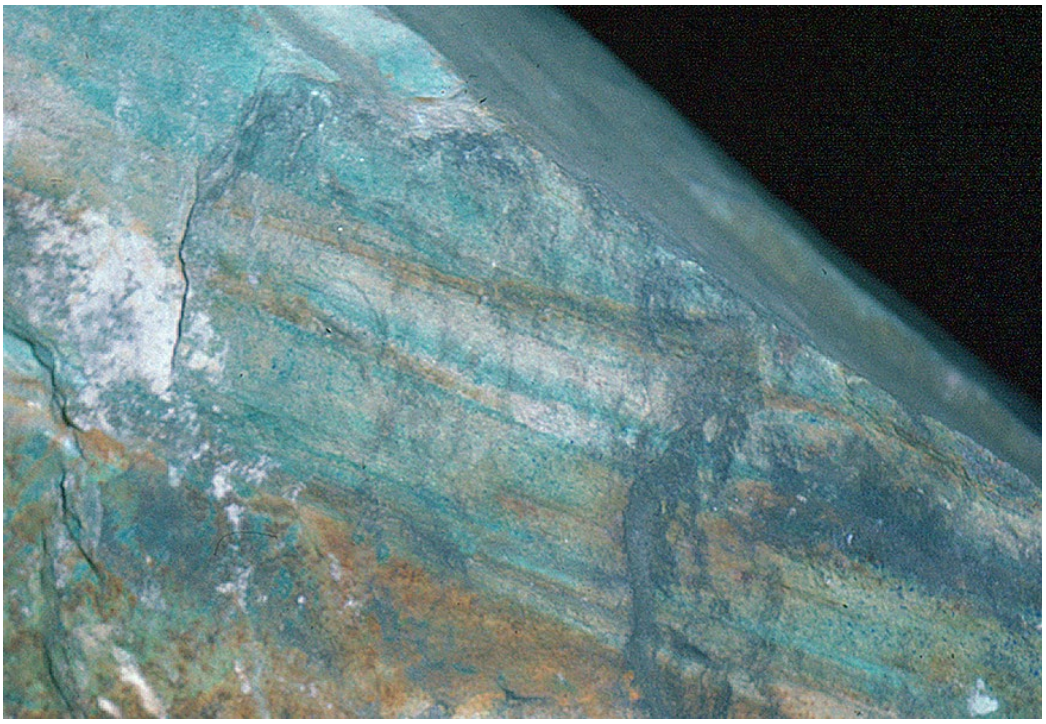
- **Management of finite underground mines by controlled access**

4.48.1: Site description

Alderley Edge SSSI, Cheshire, is designated for its mineralogical interest. The site comprises several mines where ores, chiefly of copper, with minor amounts of lead, cobalt, vanadium and arsenic, occur in sedimentary host rocks of Triassic age. The ore deposits and the sedimentary host rocks remain accessible for study within the disused mine workings. Mined from the Bronze Age until the early 20th century, Alderley Edge mine workings extend over an area of 1.5 km^2 with at least 12 km of tunnels. Important features of the mineralisation and its relationship to the sedimentary host rocks are displayed in unweathered sections in the mines. In addition, parts of the site are designated as a Scheduled Monument.

4.48.2: Challenge and actions taken

Mineral collecting can be a serious threat to the conservation of disused underground mines because the resource becomes effectively finite once the mine closes. Access control and promotion of good practice are the



Malachite, Azurite and Chrysocolla in bedded sandstones in West Mine (part of the Alderley Edge complex). © Natural England.

Engine Vein at the surface showing the fault along which mineralisation is developed. Access to the subsurface mine workings is controlled through fencing off the area, and by sealing or gating entrances to the adits. ©Natural England/Hannah Townley

most effective methods of conserving the finite mineral resource. The National Trust owns most of the land and leases the mines to Derbyshire Caving Club (DCC). As part of the conditions of the lease, no minerals may be removed from the mine. The DCC work closely with the National Trust, Manchester Museum and the County Archaeologist to manage and interpret the site.

Work by the National Trust and Cheshire County Council has made the surface features safe. Several mine shafts have been capped and access points to the mine levels have been fitted with locking gates. Members of DCC have worked underground to clear and secure the mine tunnels and the internal access between different mine levels.

Access to the mine is by prior arrangement with DCC and trips are led by experienced DCC members. Visits to certain areas are limited to small numbers of experienced cavers or mine explorers because of safety considerations. DCC also offers an open weekend every year where members of the general public can visit the more accessible and safest areas of the mine workings on guided tours.

4.48.3: Conservation outcome

Joint action by the National Trust, Cheshire County Council and Derbyshire Caving Club has secured the site and allowed safe access to the features of interest. The geological and archaeological interests of the site are being conserved while allowing controlled recreational and educational use.

4.48.4: Conservation outcome

- The Derbyshire Caving Club website provides further information on the Alderley Edge mines.

4.49: Florence Mine SSSI

An underground mine exposure site (FU) in Cumbria

Conservation issues

- **Conservation management at a deep underground metalliferrous mine**

4.49.1: Site description

Florence Mine SSSI, near Egremont, Cumbria, until recently, was the only working underground iron mine in Britain. While it was still being worked, it is one of the few underground mines in Britain regarded as an exposure site. However, since its closure in 2007 it has been regarded as a finite underground site.

The underground exposures of iron ore represent the only remaining three-dimensional exposures of the globally renowned West Cumbrian haematite deposits. The origin of these deposits remains controversial and, consequently, the exposures in Florence Mine are of major scientific importance for future studies of their genesis.

4.49.2: Challenge and actions taken

When it was a working mine, the material of interest at Florence Mine was constantly being removed and fresh exposures created. Removal of material in this way was not a problem from a conservation perspective providing the ore body was not completely worked out.

Detail of haematite vein in Florence Mine showing mammilate form of ore. ©British Geological Survey/ Brian Young reproduced with permission

Worked haematite (kidney ore) vein in Florence Mine. Pillars of ore are left in order to support the roof of the gallery. ©British Geological Survey/Brian Young reproduced with permission

The main conservation management issue was ensuring that the underground mine remained accessible and free from flooding. The mine was pumped as part of the mining operation, the cost being borne by British Nuclear Fuels Limited (BNFL), who took water from the mine to use in the cooling systems of the nearby nuclear power station at Sellafield.

However, the production of power at Sellafield ceased in 2003. The Nuclear Decommissioning Agency agreed to fund pumping for another three years, allowing time for an alternative source of energy funding to be sought. A sustainable energy solution for pumping water from the mine using hydroelectric or wind power was explored by the Florence Mine Partnership. Unfortunately a practical and economically viable long-term solution was not found. In an effort to maximise the scientific benefits from the mine, a detailed scientific description of the geological and mineralogical features exposed at the time of closure was produced. Pumping of Florence Mine BNFL ceased in 2007 and as a result, the mine became uneconomical because of the high cost of pumping. The mine closed in 2007 and it became inaccessible due to flooding, effectively destroying the scientific value of the site.

4.49.3: Conservation outcome

Unfortunately there has not been a positive conservation outcome for Florence Mine and it has now permanently closed and is completely flooded.

4.50: Abbey Wood SSSI

A buried shell bed (FB) in Bexley, Greater London

Conservation issues

- **The management of a palaeontologically significant but spatially limited resource in order to maximise the scientific value of the site**

4.50.1: Site description

Abbey Wood SSSI consists of an area of 6.7 hectares within Lesnes Abbey Woods, in the borough of Bexley, southeast London. Here, a highly fossiliferous shell bed (the Lesnes Shell Bed) is present within the Early Eocene Blackheath Formation about 1.5 m below the ground surface. Although known about since the early 20th century, the significance of the shell bed was fully realised during the 1960s when bulk collecting techniques started to yield an extensive vertebrate assemblage that includes fishes, reptiles, an internationally important mammal fauna, and vary rarely, the remains of fossil birds.

The shell bed may represent a lens of shelly sand accumulated on a shore-face in an estuary. It reaches a maximum of 2 m in thickness, but shows rapid variations in thickness and is spatially limited in extent. Combining its high palaeontological value with its limited extent indicates the vulnerability and sensitivity of this site to unmanaged exploration and collecting.

4.50.2: Challenge and actions taken

Renewed interest in the shell bed during the 1960s led to a series of excavations from which the excavated shell bed was processed for different taxonomic elements of the assemblage. Prior to designation as a SSSI in 1975, the Greater London Council Parks Department operated a permit system for excavation. The depth limit set for the excavations was a little under 50 cm, which was generally not deep enough to reach the shell bed. Excavations to reach the shell bed did take place, however, but were dependant on the discretion of the park keepers. This led to an inconsistent approach where there was relatively little control over the location of the excavations and their locations were not necessarily recorded; neither was there much in the way of systematic recording of the stratigraphy exposed, or of the finds made. This system proved to be untenable and the then Nature Conservancy Council, together with the Parks Department, developed a two-level system by which permits for shallow excavations would be processed by the Parks Department, while the Nature Conservancy Council managed permits for deep excavations. In order to avoid continuously vetting new applicants wishing to carry out

Excavation at Abbey Wood with overburden cleared down to the shell-bed. ©Laurie Baker reproduced with permission

deep excavations, a short-list of individuals permitted to excavate the shell bed was agreed. The list consisted of about ten individuals. Others applying for a permit were advised to arrange to join an excavation run by one of the named individuals.

The instigation of the permit system is the basis of ongoing management on this site. This now involves two deep excavations a year. These are at previously defined locations and up to 2000 kg of shell bed may be processed by sieving out the sand before taking the residue offsite for further processing. Significant vertebrate material is deposited with the Natural History Museum. The location and extent of excavations are accurately recorded, together with records of the succession and a report on the excavation.

Annual records of excavations, together with information acquired through the use of questionnaires during the 1970s provide a relatively comprehensive understanding of the location and extent of previous excavations and help to facilitate the management of the remaining resource.

Waste material from the excavations consists largely of sand with abundant molluscan remains, and frequent shark and ray teeth occur. The abundance of this material makes the site an educational resource in addition to its value as a SSSI, and is used by local schools, as well as groups from further afield.

4.50.3: Conservation outcome

The spatially limited, but internationally important fossil resource formed by the shell bed underlying parts of Abbey Wood, was at one time excavated in a relatively unplanned manner. The introduction of a permit system for deep excavation, the development a management plan and protocols for recording, now mean that the extent and distribution of the resource is better understood. This facilitates a more informed and sustainable use of a resource through attempting to maximise the scientific use of the site. This is reflected in the number of papers that have been published in relation to the fossil mammal assemblages of the site.

Shell bed processed onsite by wet sieving. The residues taken off site for further processing and study. ©Laurie Baker reproduced with permission

Chapter 5: Geoconservation in context

5.1: Introduction

This handbook focuses on the practicalities of site-based geological management and conservation, based mainly on experience of geological SSSI, National Nature Reserve and Local Geological Site management. It is important, however, that site-based conservation is considered in a wider context. Geological sites must be managed alongside a range of environmental interests, including species and habitats, landscapes, and archaeological heritage. Not only is it important to consider other designations and the positive role they may play in geological conservation, it is also important to understand the benefits of integrating site management. This chapter, therefore, briefly examines the value of a more integrated approach to environmental management and the context that can be established at a wider scale. It also considers the role of Geodiversity Action Planning as a framework for delivering geological conservation in a wider context.

5.2: Integrated environmental management

In simple terms, geology and geomorphology influence habitat, soil, landform, aspect and drainage pattern and are, therefore, fundamental to landscape diversity and to the management and conservation of ecosystems.

Gray (2013) reviews and elaborates the concept of geodiversity which is defined as "the natural range (diversity) of geological (rocks, minerals, fossils), geomorphological (landform, processes) and soil features. It includes their assemblages, relationships, properties, interpretations and systems" which reflects a wider environmental influence. Where biodiversity is considered to be the diversity of life, geodiversity represents abiotic diversity. Stace and Larwood (2006) examine the benefit and application of adopting 'geodiversity' across a range of natural and cultural interests and its relevance and application for people, places and nature. This integrated approach to environmental management is further developed by Gray *et al.* (2013) as a defining component in the provision of environmental services and natural capital which is illustrated through provisioning, regulating, supporting and cultural services - see Figure 5.1.

The John Lawton report 'Making Space for Nature' (Defra, 2010) further advocates this wider context around the principle of 'bigger, better and more joined up', shifting our approach to environmental management from the 'traditional' site focus to encompassing the importance of connecting sites and integrating our approach across a wider landscape – a principle that has been central to iterations of government policy in England since 2010.

In this context, geological sites and their management may provide

Figure 5.1: Diagram of abiotic ecosystem services from Gray *et al.* 2013 © 2013 The Geologists' Association. All rights reserved. Reproduced with permission

Bedrock

Fossil fuels and geothermal energy
Construction materials
Minerals, gemstones, metals

Carbon sequestration
Water quality regulation
Climate regulation
Natural hazard regulation
Erosion and flood regulation

Habitat provision
Groundwater aquifers
Burial and storage CCS

Earth history and palaeoenvironments
Environmental monitoring
Rock climbing, potholing etc.
Education
Landscape character

Soils

Nutrients and Minerals

Carbon sequestration
Erosion and flood regulation
Air quality and climate regulation
Biogeochemical processes
Water quality regulation

Habitat provision
Soil processes
Primary production – food, fibre, fuels

Geoforensics
Education

Landforms, processes and sediments

Aggregates
Freshwater from lakes

Rock cycle
Biogeochemical processes
Geomorphological processes
Natural hazard regulation
Erosion and flood regulation
Carbon sequestration
Water quality regulation

Habitat provision
Platforms

Landscape character and sense of place
Geotourism and recreation
Artistic inspiration
Folklore and sacred sites
Earth history and palaeoenvironments
Environmental modelling
Education

Atmosphere, oceans and hydrological cycle

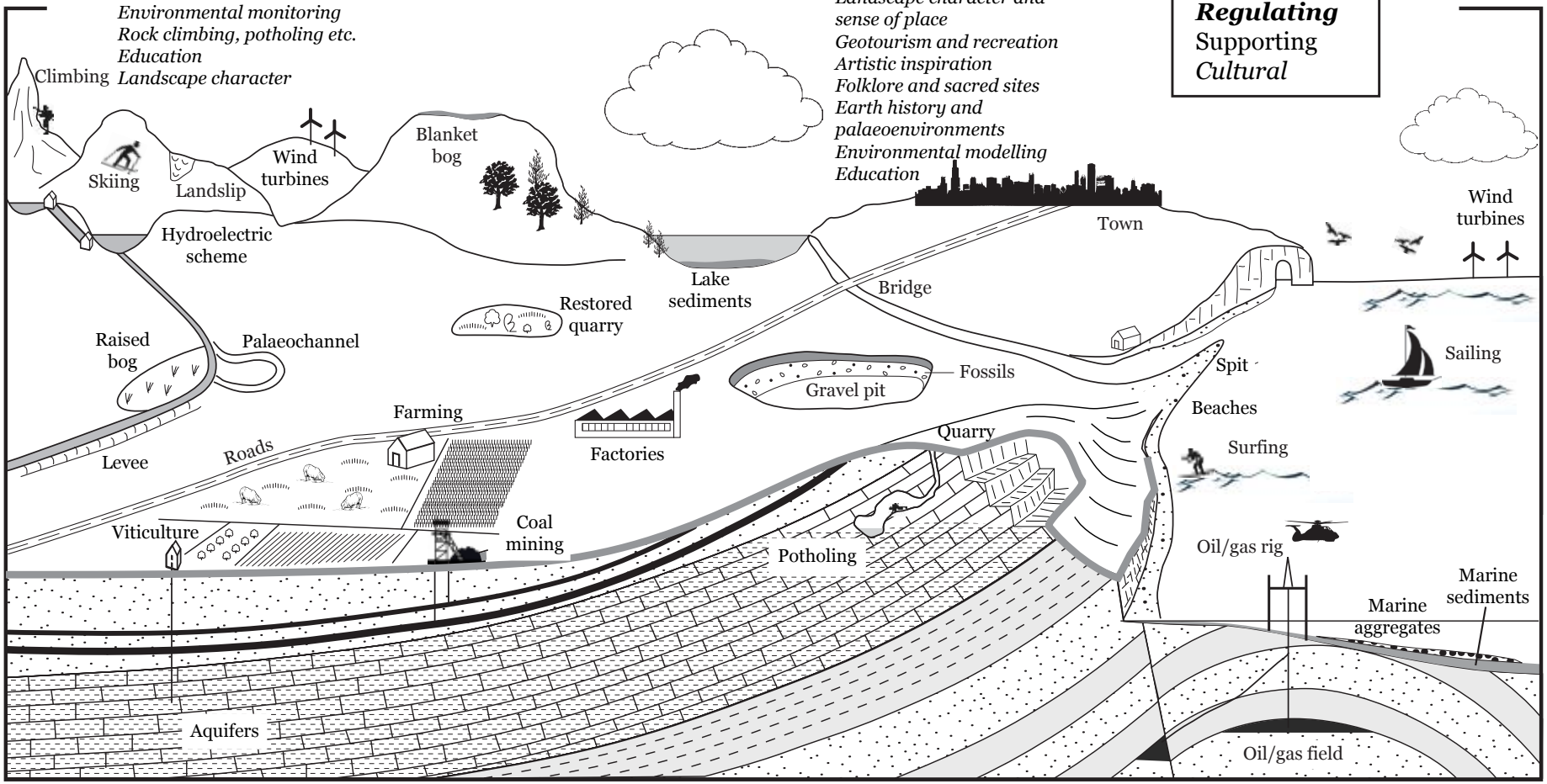
Renewable energy
Clean air and water

Dynamic circulations
Climate regulation

Habitat provision
Waves and tides

Sport and recreation
Seascape character
Education

Provisioning
Regulating
Supporting
Cultural



immediate and direct benefits to biodiversity (English Nature 2004a, 2004b, 2004c; Hopkins, 2003), Net Gain, wider Nature Recovery Areas and Nature Recovery Networks (see Nature Networks Evidence Handbook). For example, fresh rock faces, scree, soft sediment slopes and eroding and weathering sections may provide nesting sites for birds as well as habitats suitable for a range of invertebrates requiring disturbed ground. Scrub and vegetation management, to maintain geological sections, can increase the diversity of habitat from bare, open ground, through a succession of habitats to mature woodland, and can significantly benefit the wildlife of an area (for example see Kings Dyke case study). Equally, management of biological sites is often beneficial to geology. Maintaining natural processes and management activities such as scrub clearance are as important for geology as they are for biodiversity.

Wildlife sites, as well as being protected as SSSIs, may also be afforded additional protection, under the European Habitat and Species Directive, as Special Areas of Conservation (SAC) and Special Protection Areas (SPA). Included within these designations are interests such as limestone pavements and salt marshes, which are strongly geological and geomorphological, or, more specifically, habitats such as the 'vegetated sea cliffs of the Atlantic and Baltic Coasts', whose management is largely compatible with the management of their associated geology.

Integrating geological and biological site management is beneficial, therefore, in a number of ways and management prescriptions are often compatible. For example, managing scrub for geology also benefits biodiversity and vice versa. Also, wildlife designations, particularly at a European level, can provide further legislative protection to a geological site. For example, where coastal engineering works affect a geological site on an eroding cliff, an SAC designation for its habitat may provide a powerful additional mechanism for arguing against damaging coastal protection.

5.3: Landscape designation and management

Landscapes are fundamental to the character of any area and are valued for their natural, cultural and historical associations. Central to this is the way that landscapes reflect geological diversity, from rolling chalk downs to rugged uplands, and from changing land-use to variation in local building style (for example see Strategic Stone Study).

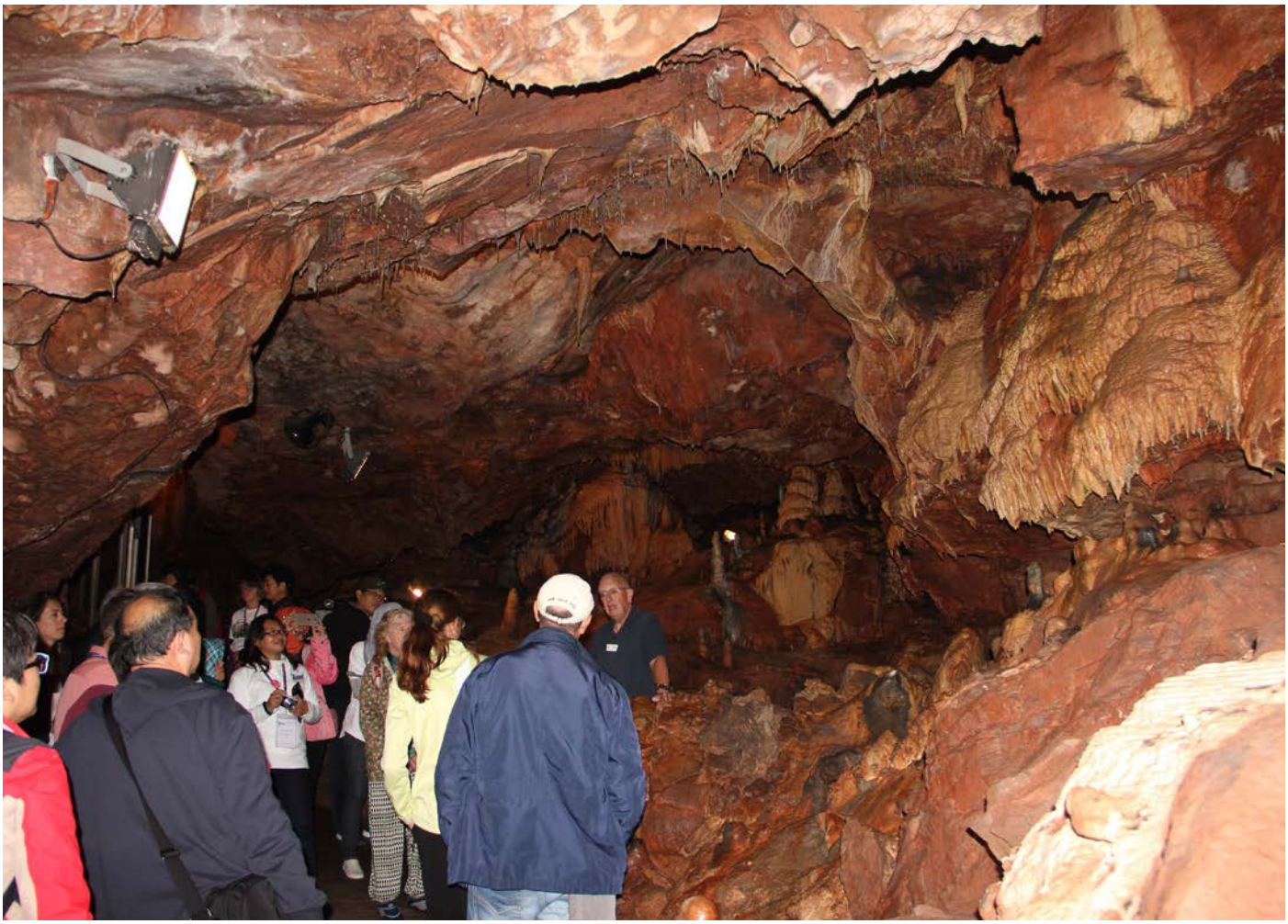
In England, there are a range of landscape designations. National Parks, Areas of Outstanding Natural Beauty (AONBs) and Heritage Coasts are considered to represent England's finest landscapes and are afforded

The waterfall at High Force on the River Tees. North Pennines UNESCO Global Geopark. The Tees cuts down through the Whin Sill into softer Carboniferous sediments, demonstrating the important role that the Whin Sill played and continues to play in influencing the geology, landscape, landuse and general character of the northern part of the Pennines. ©Natural England/Jonathan Larwood

legislative protection to maintain their quality and character. Their management is focused on conserving their natural beauty, wildlife and cultural heritage and promoting sustainable land management, in keeping with their varied character.

In a wider context National Character Areas (NCAs) have been used to divide England's landscape into 159 distinct NCAs. Each is defined by a unique combination of landscape, biodiversity, geodiversity, historical, cultural and economic associations. Geodiversity is critical to this characterisation both explicitly and implicitly defining the boundary and character of NCAs. For example, NCA 15 Durham Magnesian Limestone, is defined by the underlying Permian Magnesian Limestone which underpins the characteristic escarpment, both inland and on the coast, the associated fauna and flora, and the settlement pattern and economic history (such as limestone quarrying) of the NCA (see also 4.17 Hylton Castle case study on p.177). Comprehensive descriptions for each NCA help guide and integrate planning decisions and policy, wider land management plans and can help monitor change in the landscape (for more information, see the National Character Area Profiles).

Middle Devonian limestones exposed in Hope's Nose Quarry, Torquay. The quarry forms part of the English Riviera UNESCO Global Geopark and the location also includes early Devonian sediments, Pleistocene raised beach deposits, thrusting and mineralisation, demonstrating in a small area, the diverse geology and nature of the Geopark. ©Natural England/ Jonathan Larwood



A spectacular array of precipitation features in Kent's Cavern SSSI and Scheduled Monument. The Devonian Limestones of the English Riviera UNESCO Global Geopark contain a number of cave systems as well as associated deposits that contain fossiliferous material from the Ipswichian and younger interglacials. Managed for its geological features and its archaeology, Kents Cavern is an important visitor attraction within the Geopark. ©Natural England/ Colin Prosser

5.4: UNESCO – Global Geoparks and World Heritage Sites

At an international level UNESCO recognises geodiversity as part of its Global Geopark Programme and through the World Heritage Convention and the associated World Heritage List (Larwood *et al*., 2013).

UNESCO Global Geoparks are locally led partnerships identifying areas of internationally significant geology that, in particular, work to support sustainable economic development primarily through geotourism and ecotourism. Geoparks were established in 2000 with the creation of the European Geopark Network and subsequent widening to form the Global Geopark Network in 2004 (Jones, 2008). In 2015 the Global Geopark Network received official endorsement as the UNESCO Global Geopark Programme. Today there are eight Global Geoparks in the UK, two of which are in England. The North Pennines AONB was awarded Global Geopark status in 2003, the first in the UK (see North Pennines Global Geopark). In 2007 the English Riviera, an area encompassing Torbay in South Devon, was awarded Global Geopark status, (see English Riviera Global Geopark). more recently (2020) the Black Country Global Geopark (in the West Midlands) was endorsed as the next UK Global Geopark (see Black Country Global Geopark).

Bridport Sands forming main body of cliffs at West Bay, Bridport – Jurassic Coast World Heritage Site. The thick succession of sands containing an ichnofauna and occasional molluscan body fossils is succeeded (in the top few metres of the cliff by a condensed, but highly fossiliferous sequence of limestones belonging to the Inferior Oolite Group.

The UNESCO World Heritage Convention, established in 1972, recognises the global value of both cultural and natural heritage through inscription of World Heritage Sites – areas considered to have outstanding universal value against one or more of ten criteria (for more details see Larwood et al., 2013). There are 18 World Heritage Sites in England (July 2021), 17 are inscribed for their cultural values (these include sites such as Stonehenge and Avebury, the Palace of Westminster, and Ironbridge Gorge) and the Dorset and East Devon Coast World Heritage Site (known as the Jurassic Coast), the only natural World Heritage Site on the UK mainland. Inscribed in 2001 under Criterion viii of the World Heritage Convention ("…outstanding examples representing major stages of Earth's History…") the Jurassic Coast stretches 95 miles from the mouth of the River Exe in Devon to Studland in East Dorset. The exposures along this coastline provide an almost continuous sequence spanning the Mesozoic Era. Undoubtedly this is England's most significant geological site, placing it alongside World Heritage Sites such as the Grand Canyon and Great Barrier Reef, and arguably, England's most important natural site.

The Jurassic Coast encompasses 13 geological SSSIs (including 67 GCR sites), two National Nature Reserves, several European Habitat Directive sites (marine and terrestrial), it also overlaps with two Areas of Outstanding Natural Beauty as well as two Marine Conservation Zones. The management and conservation of the World Heritage Site is complex and, as with UNESCO Global Geoparks, is primarily based upon the established management objectives and plans for the range of designated sites that it includes. The management issues are typical of an eroding coastline which is, in places, highly developed, leading to demands for coastal protection. The Dorset coast, particularly between Charmouth and Lyme Regis, and to the immediate west of Lyme Regis, is one of the most famous fossil collecting localities in the world and much time is devoted to the management of collecting and the provision of guidance on good collecting practice (See Collecting Codes and Recording Schemes).

5.5: Geodiversity Action Planning, UKGAP and the English Geodiversity Forum

Geodiversity Action Plans (GAPs) were established in the UK in 2003 (Larwood, 2005; Potter & Burek, 2006; Dunlop *et al*. 2018) and have provided a mechanism for bringing together different organisations, groups and individuals to agree and deliver shared goals for geodiversity and geoconservation. Largely developed at a county level, there are approximately 37 Local Geodiversity Action Plans in England as well as an over-arching UK-wide Geodiversity Action Plan (UKGAP).

The delivery of the UK GAP is supported by each of the Local Geodiversity Action Plans and most recently by the formation of the English Geodiversity Forum which launched the 'Geodiversity Charter for England' in 2014 (English Geodiversity Forum, 2014). The Charter sets out a shared ambition for geodiversity across England identifying how different sectors can contribute to the development of a wider understanding of England's geoheritage, as well as in relation to its conservation and value.

Local Geodiversity Action Plans – sharing good practice (English Nature 2004d) sets out core principles for the development and delivery of a successful LGAP. LGAPs vary according to local circumstances but there are fundamental similarities between them. They are typically based on administrative boundaries, are developed through partnership, in wide consultation, and establish a measurable process. An LGAP establishes shared aims and objectives with measurable targets and actions that include:

- Geodiversity audit: an important early objective that can include a standard audit of the geology, geomorphology and geological sites of an area as well as an audit of available information and skills.

- Communication and education: promoting an understanding and wider awareness of geodiversity and encouraging participation.

- Influencing planning: influencing local plans and planning guidance to support the delivery of the action plan and geological conservation.

- Conservation and management: establishing clear goals for the conservation and management of geological sites, natural processes and the geodiversity of our landscape.

- Resources: establishing clear objectives for the resourcing (funding and people) of the action planning process.

These principles have been widely applied. They have included both the development of Company Geodiversity Action Plans (CGAPs) which focuses on the geodiversity of an organisation, often linked to mineral extraction, and the UK Geodiversity Action Plan (UKGAP), which provides an overview for the UK.

5.6: Summary

As well as the site-based approach considering a wider context for geological conservation is important. In particular, understanding the relationship between geodiversity and biodiversity (as key components of nature), the role of geodiversity in our landscapes alongside its cultural associations, and planning for geodiversity at a larger scale. This reflects a joined up approach for the natural environment and the underlying importance of geodiversity demonstrated through its contribution to environmental services and natural capital. This integrated approach brings mutual benefit for the management of geodiversity and biodiversity, and helps us better understand and connect to the natural world. Furthermore, this handbook, and the principles it sets out, makes an important contribution to the future successful recovery of nature..

Acknowledgements

Many individuals and organisations have contributed to this and the previous (2006) publication. Their contributions have included images and case studies, as well as other information relating to geological sites. Although too many to mention here, we are grateful to all those who have helped improve the quality of this publication through their individual contributions.

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Appendix A: Natural England's approach to monitoring sites

Why monitor geological sites?

Site monitoring is a fundamental part of the long-term conservation of geological sites for a number of reasons. Firstly, it is necessary to regularly check on sites to ensure that damaging activities are not occurring and that natural degradation is not preventing the site from being used for the reasons for which it is being conserved. Secondly, monitoring is an essential part of the process of positive management of geological sites, as it helps to identify what management action may be needed. Thirdly, Natural England is required to report on the condition of geological SSSIs as part of the governments' 25 Year Environment Plan Indicator G2, which relates to the condition of heritage features, including designated geological sites.

Regular monitoring allows threats to the interest of the site to be detected or foreseen, so that appropriate measures can be taken. Site monitoring in turn informs site management so that appropriate solutions to site specific problems can be devised when setting objectives for site conservation and drawing up site management plans.

Site condition reporting is performed within the statutory agencies using electronic databases. On a basic level, a condition assessment is entered under one of six fixed categories: favourable, unfavourable recovering, unfavourable no change, unfavourable declining, part destroyed and destroyed. This classification of site condition is used primarily for statistical purposes in reporting on groups of sites under various categories or on the SSSI coverage as a whole. There is also a facility to enter more detailed information on site condition.

Practical site monitoring

The Earth Science Conservation Classification (ESCC), discussed in Chapter 2, is used as the primary classification for monitoring purposes by the statutory agencies in the UK. The varying types of human activity or natural degradation processes that are likely to damage or inhibit usage of the scientific interest of a site, can be conveniently categorised according to ESCC site type (see Table 2.1, Chapter 2). Generic threats are defined for each site type and these lists are then used to create monitoring forms, termed generic favourable condition tables, for each of the site types. Examples of generic favourable condition tables for ED and FM sites, similar to those used by Natural England, are given in Tables C1 and C2.

DISUSED QUARRIES AND PITS (ED)

Attribute	Target	Yes/No	Site visit comments
Exposure of features of interest	The features of interest are exposed or can practically be re-exposed if required		
Vegetation	Vegetation is not obscuring or damaging the features of interest		
Tipping or landfill	There is no unconsented tipping or landfill obscuring or damaging the features of interest		
Tree planting	There is no unconsented tree planting obscuring or damaging the features of interest		
Engineering works	There are no engineering works, including inappropriate restoration works, obscuring or damaging the features of interest		
Planning condition observation	Planning conditions and restoration agreements or plans are being observed on site		
Geological specimen collecting	There is no irresponsible or inappropriate specimen collecting		

Table A1: Example of a generic favourable condition table, as used by Natural England, for ED sites.

The main threats to the conservation of geological exposures in disused quarries and pits (ED), as indicated on the form, are landfill, building developments, rubbish tipping, obscuring of exposure by vegetation or build-up of scree and flooding. In the case of SSSIs, the appropriate

agency is required by law to be consulted during the planning stage of a building development or landfill application or if an owner is intending to undertake an activity for which consent is required, such as dumping of rubbish. It is still, however, important to regularly monitor such sites to ensure that planning conditions are not being contravened, unconsented activities are not taking place and there is no damage by third parties, such as fly-tipping. It is also important to monitor natural degradation processes so that actions, such as scrub management and scree clearance, can be undertaken to positively manage the site for the geological interest.

FINITE MINERAL, FOSSIL OR OTHER GEOLOGICAL SITE (FM)

Attribute	Target	Yes/No	Site visit comments
Exposure of features of interest	The features of interest are exposed or can practically be re-exposed if required		
Vegetation	Vegetation is not obscuring or damaging the features of interest		
Tipping or landfill	There is no unconsented tipping or landfill obscuring or damaging the features of interest		
Tree planting	There is no unconsented tree planting obscuring or damaging the features of interest		
Engineering works	There is no unconsented tree planting obscuring or damaging the features of interest		
Geological specimen collecting	There is no irresponsible or inappropriate specimen collecting		

Table A2: Example of a generic favourable condition table, as used by Natural England, for FM sites.

The main threats to the conservation of geological exposures in disused quarries and pits (ED), as indicated on the form, are landfill, building developments, rubbish tipping, obscuring of exposure by vegetation or build-up of scree and flooding. In the case of SSSIs, the appropriate agency is required by law to be consulted during the planning stage of a building development or landfill application or if an owner is intending to undertake an activity for which consent is required, such as dumping of rubbish. It is still, however, important to regularly monitor such sites to ensure that planning conditions are not being contravened, unconsented activities are not taking place and there is no damage by third parties, such as fly-tipping. It is also important to monitor natural degradation processes so that actions, such as scrub management and scree clearance, can be undertaken to positively manage the site for the geological interest.

Specimen collecting is generally not considered to be a damaging activity on most types of geological site, if carried out in a responsible manner. Responsible collecting on exposure sites usually does not result in damage to the interest, as removal of rock should reveal more material of the same type. In fact, on sites which are rapidly eroding or where active quarrying is taking place, material will be lost if not recovered. On these sites, responsible collecting is an essential part of site conservation and is often encouraged by the statutory agencies.

It is generally only on finite sites, such as mineral and fossil sites with a strictly finite resource, that over-collecting becomes a serious threat to conservation. In extreme cases, over-collecting can result in complete destruction of the resource. On many SSSIs with a sensitive or finite resource, there is a legal requirement on owner/occupiers and third parties to obtain consent from the appropriate statutory agency before collecting or allowing specimens to be collected. This applies to several FM and FD sites and to all cave sites (IC). In monitoring such sites, any evidence of unconsented specimen collecting may indicate that the site is being damaged, but this needs to be measured against the extent of the remaining resource and usually requires expert judgement.

It is important to note that site access for third parties (that is permission to enter a site for scientific and/or educational purposes) is not used by the statutory agencies as a criterion in determining site condition. While maintaining site access for scientific and, where appropriate, educational purposes is a desirable goal in site conservation, the fact that a landowner may refuse permission to third parties to enter a site does not automatically mean that the site is in unfavourable condition.

Under the provisions of the Countryside and Rights of Way Act (2000), Natural England has power of entry to any SSSI in England for monitoring purposes and to enforce positive management of the site, if necessary. There is, however, no requirement by law on any landowner to permit access to third parties for scientific and/or educational purposes. Site access can be an important criterion for determining the condition of certain locally important sites that have been selected primarily for their educational value.

Monitoring procedure

The first step in monitoring a site is to choose the correct generic favourable condition table, according to its ESCC code. As noted above, some sites can have more than one ESCC code. If a site has been previously monitored and site-specific conservation objectives have been produced (see Chapter 2), these should be used in conjunction with the generic favourable condition table to assess site condition.

For statutory sites, the SSSI citation is used to determine what features are designated. More detailed descriptions of the interest features on SSSIs are available to statutory agency staff in site management documents. Site Management Briefs (SMBs) were produced for all geological SSSIs in England during the early 1990s. Similar documents exist for some locally important sites, such as some LGS. The SMBs, and equivalent documents in the other agencies, are the primary reference source in undertaking site monitoring, providing a baseline against which changes in site condition can be measured.

The SMBs contain general descriptions of the scientific interest features, GCR and SSSI citations and maps, photographs of the site and, in many cases, annotated maps of the sites depicting the location of interest features and photographs. Potential threats to the interest features and other information relevant to site conservation are normally detailed. In addition, a program of production of site-specific conservation objectives has been underway in Natural England since 2002. These provide very specific information on what condition the interest features should be in for the site to be considered as favourable.

The second step in monitoring is to visit the site and to use the site management document to locate the special interest features. The distribution of interest features on geological sites is very variable. Some, such as certain mineral vein interests, may be very localised at one or two places within a site. Others, such as many types of stratigraphic interest, may be distributed across the entire site. Once the interest features

have been located, they should be assessed using the appropriate generic favourable condition tables and, if they exist, the site-specific conservation objectives.

In addition to visual assessment, fixed-point photography should be used to record the condition of the interest features. It is generally sufficient to record the positions from which photographs have been taken on a map of the site. In this way, further site monitoring visits can reproduce similar results and a long-term photographic record of the site can eventually be produced.

It is normally necessary only to assess the general condition of the interest features. If a site is notified for a stratigraphic interest in a particular series of beds, for example, and the location of these beds is known from the site management document or conservation objectives, then it is sufficient to check that the beds are well enough exposed to demonstrate the stratigraphic interest. It should not be generally necessary for monitoring purposes to re-investigate the geology of the beds to check that they do actually demonstrate the features for which the site was selected. This should have been done as part of the site selection process.

In general, therefore, monitoring does not have to be performed by an expert in the particular branch of geology for which the site is notified, provided that high quality site management documents exist. There are, however, exceptions where monitoring may require more expert assessment. Active process sites (IA) are one example where this simple approach to monitoring may not be sufficient and expert assessment may be necessary. Mine dumps (FD) are another example where assessment of site condition by an expert mineralogist may be required, as a non-expert is unlikely to be able to identify the minerals of interest and the overall condition of the resource. For the purpose of basic condition assessment and statistical reporting, a site can be considered to be in favourable condition if it matches the general criteria of the favourable condition table. If any of the attributes of the site do not meet the criteria, the site may not be in favourable condition and a further assessment may be required. Because there is often a significant degree of subjectivity involved in using the generic tables, it is important to produce site-specific objectives against which future site condition can be measured.

Appendix B: Chronology of geoconservation in England

1873: The first example of geoconservation in England

Carboniferous ‘tree’ stumps (stigmarias) exposed when levelling ground at a Sheffield ‘lunatic asylum’ at Wadsley in Sheffield, were preserved through enclosing them within two small sheds that both protected the fossils from weathering and allowed access for visitors.

1942: The Scott Report

The Report on Land Utilisation in Rural Areas, recommends that the Central Planning Authority, in conjunction with scientific societies, should prepare details of areas desired as nature reserves (including geological parks) and take the necessary steps for their reservation and control. This is the first mention of the consideration of geoconservation at a national level.

1945: National Geological Reserves in England and Wales

This report by the Geological Reserves Sub-Committee of the Nature Reserves Investigation Committee, identified “a list of sites meriting permanent protection as Geological Reserves of national importance”, and marked the first steps towards developing a systematic approach to the conservation of geoheritage on a national scale.

1947: Command 7122 – Conservation of nature in England and Wales

This report by the Government-appointed Wild Life Conservation Special Committee, recognised geoconservation alongside wildlife conservation and made recommendations as to how the Government could engage in a national nature conservation effort and led to the passing of the National Parks and Access to the Countryside Act and the creation of a national conservation body, the Nature Conservancy.

1949: The National Parks and Access to the Countryside Act and the Nature Conservancy

The Government passed the National Parks and Access to the Countryside Act and established, by Royal Charter, the Nature Conservancy. This put in place a legal framework for nature conservation, including geoconservation, and a government body responsible for its delivery. The Act empowered the Nature Conservancy to establish National Nature Reserves (NNRs) for the purposes of nature conservation. It also recognised that it would be a long time, if ever, before all the important wildlife and geological sites could be acquired

as nature reserves. It contained a provision, therefore, for the Nature Conservancy to notify local planning authorities of important areas, not yet managed as nature reserves, as Sites of Special Scientific Interest (SSSIs), by reason of their flora, fauna or geological or physiographical features. Although the Act gave no direct protection to SSSIs, it enabled a local planning authority, once notified of an SSSI, to protect it from adverse development under the controls of the planning system.

1950: The first professional geoconservationist

William Macfadyen appointed as the Nature Conservancy's first geologist and most probably as the first professional geoconservationist in the World.

1968: The origins of Earth Heritage magazine

The first issue was produced of the 'Geological Section of the Nature Conservancy Information Circular', which later evolved into what is now Earth Heritage magazine.

1973: The Nature Conservancy Council

The Nature Conservancy Council Act split the Nature Conservancy into two parts. The executive part, including the geoconservation function, was reconstituted as the Nature Conservancy Council (NCC), an independent council with greater autonomy. The research arm of the Nature Conservancy remained within the Natural Environment Research Council as the Institute of Terrestrial Ecology.

1977: The Geological Conservation Review

The Geological Conservation Review (GCR) was initiated to establish a more systematic and scientifically rigorous approach to the identification of nationally important geological sites than had previously been the case. The GCR provided a systematic site assessment and selection exercise carried out on a Great Britain scale and involved a wide range of geoscience specialists from academia, museums and industry, assessing sites within discrete subject areas. All geological sites considered at a national level for conservation as SSSIs have been subject to thorough assessment by specialists in their field through the GCR process. The main phase of the GCR was completed in 1990 and site descriptions were published by the Joint Nature Conservation Committee (JNCC) up until 2010, and since 2011, as Special issues of the Proceedings of the Geologists' Association.

1981: The Wildlife and Countryside Act

This Act improved arrangements for the effective conservation of SSSIs. Under the 1949 Act, only local planning authorities had to be informed about the existence of an SSSI. The 1981 Act required the statutory nature conservation bodies to inform all owners and occupiers, as well as planning authorities and the government, about the location of an SSSI. Owners and occupiers also had to be informed about the nature of the features which were identified as being of special scientific interest and about the types of operations or activities that may damage these special features. The 1981 Act also contained a provision enabling a local planning authority to make a Limestone Pavement Order, on either landscape or nature conservation grounds, to prevent the removal of rock from limestone pavement areas. The provision for notification of geodiversity sites as SSSIs has been widely adopted across Great Britain and is the major tool used to deliver the conservation of nationally important geological and geomorphological sites. In England alone, there are currently around 1,150 SSSIs notified for a geodiversity interest, almost 30 per cent of the total number of English SSSIs.

1990: Earth science conservation in Great Britain – a strategy

In 1990, the Nature Conservancy Council (NCC), working with the geoscience and geoconservation communities, published a strategy which, for the first time, set out a framework for geoconservation in Great Britain. The Strategy had six main themes that provided direction for geoconservation in the 1990s. These were:

- maintaining the SSSI series based on the GCR
- expanding the Regionally Important Geological and geomorphological Sites RIGS network
- developing new conservation techniques
- improving site documentation
- increasing public awareness
- developing international links.

1990: Regionally Important Geological and geomorphological Sites (RIGS)

The 1990 strategy document formally introduced the concept of RIGS. Since 1990, the RIGS movement has expanded rapidly and served to establish a voluntary geological conservation sector at regional and local level, resulting in conservation activity taking place on hundreds of sites. RIGS are locally or regionally important sites usually identified

within a county or region that are considered worthy of protection for their geological or geomorphological importance. RIGS are selected and managed by RIGS groups, sometimes called trusts or geoconservation groups, and are typically made up of locally-based geologists, conservationists, teachers, museum workers and planners, usually working at a county level. Although RIGS have no statutory protection, the details of many RIGS have been passed to local planning authorities and these sites receive some protection through planning policies relating to the relevant local plan. The RIGS movement has resulted in increased conservation activity and involvement in geoconservation at a regional and local level.

1990: The Environmental Protection Act

This Act led, in 1991, to the Great Britain-wide conservation agency, the Nature Conservancy Council, being split into three country-based agencies: the Countryside Council for Wales, English Nature and Scottish Natural Heritage. Alongside these three agencies, the overarching Joint Nature Conservation Committee (JNCC) was created, having responsibility for research and advice on nature conservation at both United Kingdom and international levels.

1993: The Malvern International Conference, Geological and Landscape Conservation

This conference was the first large-scale international conference on geoconservation to be held in the UK, and played an important role in raising the profile of geoconservation and building an international geoconservation community.

1993: ProGEO formed

Established in 1993, the European Association for the Conservation of the Geological Heritage (ProGEO) has subsequently provided the main focus for promoting and developing geoconservation across Europe.

1994: Planning Policy Guidance 9: Nature Conservation (PPG9)

In 1994, this planning policy guidance provided the first recognition of RIGS within the planning system.

1994: First text book on geoconservation

Earth Heritage Conservation, published by the Geological Society and the Open University provides a structured course in geoconservation.

1999: The Association of UK RIGS Groups (UKRIGS)

Between 1990 and 1999 the number of RIGS groups and their levels of activity continued to grow, leading to RIGS groups or equivalents being established in most areas of England and Wales, and in some areas of Scotland and Northern Ireland. A consequence of this growth was an increased national profile and momentum and a desire for greater national recognition and independence from established conservation bodies. Thus, by 1999, an independent national umbrella body, the Association of UK RIGS Groups (UKRIGS), was established.

1999: RIGS handbook

This handbook provided advice and guidance on good geoconservation practice to RIGS groups across the UK.

2000: The Countryside and Rights of Way (CRoW) Act

This Act greatly strengthened legislation relating to the conservation of geology, geomorphology and wildlife in England and Wales. It placed emphasis on management rather than just conservation of SSSIs. It encouraged partnerships to help deliver positive management on SSSIs, but where appropriate management could not be secured through agreement, the CRoW Act made it possible to impose management. This made it possible to tackle sites that were deteriorating through neglect, as well as those suffering from deliberate damage. The Act also required that all public bodies should conserve and enhance SSSIs, meaning that government departments, local planning authorities and privatised utilities had to consider how their functions may affect SSSIs, and plan their work accordingly. The CRoW Act also made it an offence for anyone to knowingly or recklessly damage an SSSI, providing significantly more power in dealing with damage on SSSIs resulting from third-party activities, such as irresponsible fossil or mineral collecting.

2000: Establishment of the European Geopark Network

Developed from the bottom-up, the Geopark movement set out to conserve geological heritage through using it as a means of promoting sustainable development through geotourism. In the year 2000, four founder territories in France, Greece, Germany and Spain came together

to establish a European Geopark Network (EGN) encouraging others to join them.

2001: The UKRIGS Development Strategy

This document set out, for the first time, an independent vision and series of objectives aimed at supporting the RIGS movement.

2001: The Dorset and East Devon Coast (the Jurassic Coast) World Heritage Site

In 2001, the first World Heritage Site in England to be inscribed on account of its geology came into being, with the inscription of the Dorset and East Devon Coast. This provided geoconservation in Great Britain with an increased profile and an international stage on which to develop and share good practice. Of particular importance were the opportunities to promote geology, geomorphology, geoconservation and geotourism to a wide audience.

2002: Local Geodiversity Action Plans

By 2002, it was increasingly accepted that effective geological conservation required a planned, holistic and participative approach and that a site-based approach alone was not enough. Thus, building on the approach taken to the conservation of biodiversity, the concept of geodiversity action planning was initiated. This included both Local Geodiversity Action Plans (LGAPs), produced for a particular geographical area, and Company Geodiversity Action Plans (CGAPs), produced for the holdings of a business such as a minerals extraction company. These plans integrate objectives for national and local conservation designations with those for other geological and geomorphological features of interest and are developed and delivered in partnership.

2002: The Aggregates Levy Sustainability Fund

The Aggregates Levy Sustainability Fund (ALSF) provided, for the first time, a very significant source of funding for geoscience and geoconservation projects. The ALSF arose from the Aggregates Levy, a tax on the commercial exploitation of primary aggregate, introduced in Great Britain in April 2002. The Aggregates Levy was intended to bring about environmental benefits by making the price of aggregates better reflect the cost of the impacts of aggregate extraction on the environment, and by encouraging the use of recycled materials. The importance of

the Aggregates Levy for geoscience and geoconservation was that approximately 10 per cent of the money raised was allocated to the ALSF, part of which is used to fund projects delivering geoconservation or interpretation in any area affected by aggregate extraction. Eligible activities included site management, interpretation, access provision, promotion and specimen rescue. The ALSF was also a major funder of the geodiversity audit aspect of LGAPs. The ALSF made a major contribution to geoconservation, education and awareness raising, through channelling significant sums of money into these areas of activity, and was been of immense importance in supporting the work of the RIGS movement.

2003: Geology Trusts

The growth and increasing diversity of the RIGS movement led to some RIGS groups forming regional partnerships to co-ordinate their work. One such group, The Geology Trusts, was launched in 2003 and has been successful in securing resources and delivering projects.

2003: European Geoparks in England

By 2003, territories in England had engaged with the European Geopark Network (EGN), and Geoparks firstly the North Pennines and then the Abberley and Malvern Hills (later to resign from the EGN) were accepted into the EGN. These Geoparks introduced a new conservation 'label' into England and operate on a landscape, rather than site-based scale, are focussed on geotourism-led sustainable development and have strong support from their local communities.

2003: The first text book on Geodiversity

This book, written by Murray Gray (Gray 2003), was the first to focus on the relatively new term and concept of geodiversity and played a major role in raising the profile and credibility of geodiversity as a serious discipline of relevance to academic study as well as to policy and practice relating to land management, land use, conservation and tourism.

2004: Global Geoparks Network formed

The EGN and the National Geoparks Network of the People's Republic of China come together to form the Global Geoparks Network. This means all Geoparks in England admitted into the EGN became Global Geoparks.

2005: Planning Policy Statement 9: Biodiversity and Geological Conservation (PPS9)

The publication of this planning policy statement represented a major step forward in terms of achieving greater recognition for geoconservation in the planning system in England. This policy statement, which replaced PPG9 (1994), gave geoconservation a higher profile by including it in its title, and through making more specific reference to it throughout the policies. In particular, it made a number of important statements about the need for the planning system to deliver geoconservation across the whole landscape, not just on protected sites.

2006: Local sites: guidance on their identification, selection and management

This guidance, produced by the Department for the Environment, Food and Rural Affairs, marked increasing recognition of RIGS alongside their wildlife equivalents. The guidance encouraged a pulling-together of existing geodiversity and biodiversity local site schemes, and the bodies that ran them, to create a more integrated and consistent approach to identification and management of local sites. The guidance encouraged adoption of the generic term 'Local Sites', with the option to differentiate 'Local Sites' into 'Local Wildlife Sites' and 'Local Geological Sites'.

2006: The creation of Natural England

The creation of Natural England, through the merger of English Nature with parts of the Countryside Agency and the Rural Development Service, reflected recognition that the natural environment is best managed in an integrated, holistic way. Natural England brought geology, geomorphology, soils, habitats, landscape and public access and recreation together, creating an organisation where geoconservation could be delivered as part of the management of the whole natural environment.

2008: The English Riviera Global Geopark

The English Riviera Geopark, in Devon, was accepted into the Global Geopark Network whilst Abberley and Malvern Hills resigned from the Network, maintaining the number of Global Geoparks in England at two.

2008: The first book on the History of Geoconservation

This book, arising from a conference held in 2006 (Burek & Prosser 2008), was the first to explore the origins, and development of geoconservation in the UK and more widely.

2009: The journal Geoheritage launched

Established through the efforts of the European Association for the Conservation of the Geological Heritage (ProGEO), Geoheritage, became the first scientific journal devoted to geoheritage and its conservation.

The national umbrella body for RIGS / local geoconservation groups, UKRIGS, is rebadged to become GeoConservationUK.

2011: ALSF terminated

Financial readjustment following the global downturn resulted in termination of the ALSF in England, cutting a source of funding that has played a major role in supporting geoconservation projects, especially those led by local geoconservation groups, since the Fund's introduction in 2002.

2011: The UK Global Geopark Forum (UKGGF)

This was established in order to coordinate and support the maintenance and development of Global Geoparks in the UK. With representation on the Forum including all UK Global Geoparks, country conservation agencies, the British Geological Survey and the Geological Society, its aims include sharing good practice, co-ordinating new Geopark applications from the UK and providing support and guidance to those considering making an application to become a Global Geopark.

2011: Geoconservation for science and society: an agenda for the 21st Century

This conference, the Geologists' Association Annual Conference for 2011, brought together all those interested in geoconservation in the UK, recognising the progress made to date, but focussing on the future challenges and the opportunities available to ensure that geoconservation meets these challenges in a way that it continues to be relevant in the years ahead. The proceedings of the conference, which was held in Worcester, were published as a Special Issue of the Proceedings of the Geologists' Association in 2013.

2011: UK Geodiversity Action Plan (UKGAP)

The UKGAP, which provided, for the first time, an agreed framework for geodiversity action across the UK, and which enabled action against agreed objectives to be reported upon, was launched at the Geologists' Association Annual Conference, Geoconservation for science and society: an agenda for the 21st Century.

2012: National Planning Policy Framework (NPPF)

This new planning policy for England replaced all previously existing Planning Policy Statements (PPSs), including PPS9: Biodiversity and Geological Conservation, and Mineral Policy Statements (MPSs), reducing over 1000 pages of planning guidance to just 50. In terms of geoconservation, although not perfect, it retained clear policy guidance on geoconservation which, given the concentration of all planning policy guidance into one place, helped to raise the profile of geodiversity and geoconservation amongst planners and developers.

2013: English Geodiversity Forum

Mirroring an approach taken in Scotland, and facilitated by Natural England, the English Geodiversity Forum, made up of a wide range of organisations, societies, groups and individuals, was formed in order to provide a focus and voice for geodiversity and geoconservation in England.

2014: Geodiversity Charter for England

Again, mirroring the approach taken in Scotland, this was launched in the Palace of Westminster, by the Secretary of State for Natural Environment and Science. The aims of the Geodiversity Charter for England were to provide a focus for geoconservation action in England, to encourage partnership working to promote geodiversity, and to widen understanding of the importance of geodiversity and geoconservation.

2015: UNESCO Global Geopark Programme established

UNESCO ratify the creation of UNESCO Global Geoparks.
UNESCO, in effect adopting the Global Geopark Network. The existing geoparks in England become UNESCO Global Geoparks.

2018: National Planning Policy Framework (NPPF) revised

A new NPPF for England is published with less explicit reference to geoconservation than the 2012 original.

2020: The Government Publishes its G2 indicator on Heritage Features

In line with “A Green Future: Our 25 Year Plan to Improve the Environment” the Government publishes its first G2 Indicator on the condition of heritage features, including designated geological sites.

2020: The Black Country becomes a UNESCO Global Geopark

The Black Country is accepted into the UNESCO Global Geopark Network, bringing the number of UNESCO Global Geoparks in England to three.

2020: Saltwells declared a geological National Nature Reserve

Saltwells, a new geological NNR is declared within the Black Country UNESCO Global Geopark.

2021: A proposal for an International Geodiversity Day

A proposal for an International Geodiversity Day is approved by UNESCO.

2022: Celebration of the first International Geodiversity Day

The first International Geodiversity Day took place on the 6th October 2022 and was marked by events around the world.

Appendix C: Organisations with an interest in geoconservation

Organisation	Function	Website
Natural Resources Wales	Government agency responsible for geological conservation in Wales	www.naturalresourceswales.gov.uk
Natural England	Government agency responsible for geological conservation and some countryside issues, including landscape protection for England	www.gov.uk/government/organisations/natural-england
Nature Scotland	Government agency responsible for geological conservation in Scotland (formerly known as Scottish Natural Heritage)	www.nature.scot
Department of Agriculture, Environment and Rural Affairs, Northern Ireland	Government department responsible for geological conservation in Northern Ireland	https://www.daera-ni.gov.uk/
Joint Nature Conservation Committee	Government agency responsible for the Geological Conservation Review (GCR) and for UK-wide geological conservation issues	www.jncc.gov.uk
GeoConservationUK	Promotes (and manages some) Local Geological Sites for education and public benefit	https://geoconservationuk.org/
The Geology Trusts	A partnership of county groups working as 'Trusts'	www.thegeologytrusts.org
Geoconservation Committee, Geological Society of London	The aim of the Geoconservation Committee is to help conserve the diverse geology and rich geological and geomorphological heritage of the United Kingdom, and to pass it in good order to future generations for their investigation, education and enjoyment.	https://www.geolsoc.org.uk/geoconservation-committee
ProGEO	The international association for geological conservation	www.progeo.ngo/
British Institute for Geological Conservation	An independent group of geoscientists committed to geological conservation	https://geoconservationlive.org/bigc/
English Geodiversity Forum	A collective voice for England's geodiversity, representing the wide interests of geodiversity and geoconservation	
Geologists' Association	An organisation serving the interests of both amateur and professional geologists in the UK	https://geologistsassociation.org.uk/
Geological Society of London	UK national society for professional geoscientists, hosts the Geoconservation Committee	https://www.geolsoc.org.uk/

Organisation	Function	Website
Dorset and East Devon Coast World Heritage Site	Management of the Dorset and East Devon Coast World Heritage Site	https://jurassiccoast.org/
UNESCO	Selection and inscription of World Heritage Sites	https://whc.unesco.org/en/criteria
UNESCO Global Geoparks	Responsible for UNESCO Global Geoparks Programme	www.unesco.org/new/en/natural-sciences/environment/earth-sciences/unesco-global-geoparks/
European Geopark Network	Coordination of European Geoparks	www.europeangeoparks.org
World Heritage UK (WHUK)	Organisation responsible for networking, advocacy and promotion for the UK's 32 outstanding World Heritage Sites	www.worldheritageuk.org
Geological Curators Group	An organisation dedicated to improving the status of geology in museums and raising the standard of geological curation	https://www.geocurator.org/
British Geological Survey	National geological survey for Great Britain	www.bgs.ac.uk
Quaternary Research Association	Organisation for Quaternary researchers in the UK.	www.qra.org.uk
British Society for Geomorphology	Professional organisation for geomorphologists in Great Britain	www.geomorphology.org.uk
British Caving Association	Organisation for British caving	www.british-caving.org.uk
British Cave Research Association	Promotes the study of caves and associated phenomena by supporting cave and karst research	www.bcra.org.uk
Palaeontological Association	Professional organisation for palaeontologists	www.palass.org
Association for Heritage Interpretation	Professional network for heritage professionals working to interpret natural and cultural heritage	www.ahi.org.uk
Earth Heritage Magazine	Geological and landscape conservation magazine	https://www.earthheritage.org.uk/
Royal Geographical Society (with IBG)	UK national society for professional geographers	www.rgs.org/

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This is PART 3 of 3:
ISBN 978-1-78367-377-3
Natural England General Publication NE789

NATURAL ENGLAND