Chapter 6 Earth heritage conservation

Introduction

The need to take active measures to conserve our Earth heritage is, perhaps, less obvious than for biological sites which we need to conserve to ensure the survival of endangered animals, plants and habitats. Rocks are, after all, hard and durable, and some have existed for many millions of years. Similarly, some mature landscapes have remained almost unchanged for centuries. However, natural resources, such as crushed rock, sand and gravel, are required to meet the demands of modern society and careful planning is required to ensure that any important geological feature is not destroyed in this process.

Threats to the Earth heritage

In modern society, there is an increasing need for waste disposal sites. Quarries, gravel pits, old mines and caves have all been used to fulfil this need and some historically important sites have been lost to science as a result.

Some engineering methods can also pose problems for Earth heritage sites. In protecting coastal cliffs from further erosion, rock exposures of value to science may be covered by engineering works (Figure 62). Such practices can also cut off the sediment supplies which feed and maintain shingle bars, beaches, saltmarshes and mud flats, causing them to become eroded by the action of the sea. Similarly, river engineering works have altered natural fluvial geomorphological features, and commercial and industrial developments have destroyed or covered sites. Even the shape of the land has been changed as features are levelled or exploited to extract materials for the construction industry, and the planting of coniferous trees in upland areas has damaged geomorphological features and obscured geological exposures.

However, development and the effective conservation of the Earth heritage are not mutually exclusive if properly co-ordinated.

Quarrying and Earth heritage conservation: threats and benefits

Rock exposures created by quarrying and related activities have played a key role in the interpretation of Britain's geology and have proved vital to the development of the Earth sciences over the last 200 years. Although active quarrying and conservation of the Earth heritage may not appear to be compatible, because quarrying is essentially a destructive process, such extraction has also revealed more exposures of rock formations, mineral veins and fossil taxa than would otherwise have been known from natural exposures alone. Therefore, quarrying, and indeed road construction, can be both a threat and a potential benefit to our knowledge of Earth heritage. Co-operation between the extraction industry and conservation interests can strike a mutually beneficial balance.

Of course, even when a site has been selected for Earth heritage conservation, it can still be threatened by, for example, a change in use or natural degradation. Conservation is, therefore, not only a matter of site protection and countering potential threats, but also of active management for the long-term maintenance of the features of special interest.

The remainder of this chapter outlines the history of Earth heritage conservation in Britain, explains the current legal framework for the protection of Earth heritage sites, and considers the strategy adopted for practical Earth heritage site conservation.

The history of earth heritage conservation in Britain

Earth heritage conservation in Britain dates back to the mid-nineteenth century. An early example of the concern to conserve important sites is the action taken to protect Fossil Grove in Glasgow, where well-displayed stumps from Carboniferous tree-like plants called lycopods were enclosed in 1887. They are still protected by Glasgow City Council (Figure 63).

In 1912 the Society for the Protection of Nature Reserves was for med, and gradually there emerged a more systematic approach for identifying sites that merited conservation. In 1941 the Society convened a confer ence to consider the place of conservation in post-war Britain. The outcome was the establishment of the Nature Reserves Investigation Committee in 1943. This committee identified no fewer than 390 geological sites in England and Wales. A fur ther 60 geological sites were identified in a subsequent repor t on Scotland.

This early work prompted the Government to create the Wildlife Conservation Special Committee (England and Wales) to examine ways in which the Government could further support the national nature protection effort. Their report, Conservation of Nature in England and Wales (Cmd 7122, 1947), laid the foundation for nature conservation. It recognised a twin approach to nature conservation in which scientific activity developed in parallel with aesthetic and recreational concerns.

In 1949 the Nature Conservancy was created by Royal Charter. The Charter empowered the Nature Conservancy to establish National Nature Reserves for the purposes of nature conservation, including geological and 'physiographical' (geomorphological) conservation.

In the same year, Parliament passed the *National Parks and Access to the Countryside Act 1949* — a milestone in the development of conservation legislation. The Act led to the creation of the National Parks in England and Wales, conferred powers on local authorities to create local nature reserves and required the Nature Conservancy to notify local authorities of the location of Sites of Special Scientific Interest (SSSIs) by reason of their flora, fauna or geological or physiographical features. The prominence of Earth heritage considerations in the thinking of the Committee, and subsequently the Act, owes much to the foresight of Sir Julian Huxley and other members of the Committee. While the Act gave no direct protection to SSSIs, Town and Country Planning legislation provides the means of protecting sites from being destroyed by development.

During the 1950s, '60s and '70s, Earth science staff of the Nature Conservancy (1949–1973) and then the Nature Conservancy Council (1973–1991) contributed to the development of the SSSI and National Nature Reserve (NNR) series. A significant development in wildlife conservation was the Nature Conservation Review (1977) which, between 1966 and 1970, evaluated areas of national biological importance in Britain. The Geological Conservation Review commenced in 1977, to provide a parallel audit of the Earth heritage in Great Britain.

At the same time, much activity by the Nature Conservancy Council was devoted to the local and day-to-day concerns of protecting the sites. This was carried out largely by participating as consultees in the development control process of the Town and Country Planning Acts. Also, during this period, voluntary conservation bodies, notably County Naturalists' Trusts, established some Earth heritage sites as non-statutory reserves, while further sites were acquired by local authorities as Country Parks or statutory local nature reserves.

The next major step forward was the enactment of the *Wildlife and Countryside Act 1981*, which improved arrangements for the effective conservation of SSSIs. An additional Earth heritage aspect of the Act, with important implications for landscape conservation, was the provision for Orders to protect areas of limestone pavement.

The *Environmental Protection Act 1990* and the *Natural Heritage (Scotland) Act 1991* subdivided the Nature Conservancy Council into three country-based organisations — the Countryside Council for Wales, English Nature and Scottish Natural Heritage. This re-organisation reflected the desire to bring nature conservation closer to local people. It also afforded the opportunity for the three organisations to develop independent approaches to the subject. Where common concerns and issues arise, such as in setting common standards of practice, the agencies operate through the Joint Nature Conservation Committee (JNCC). The JNCC also has responsibility for research and advice on nature conservation at both United Kingdom and international levels.

Outside the SSSI network the protection of Earth heritage sites is undertaken for the most part by voluntary and locally based groups, often with support from national Earth science societies and institutions. The work of the Geologists' Association and its regional groups is particularly important, and the Conservation Committee of the Geological Society of London is a forum that brings together organisations and groups concerned with Earth sciences and site conservation.

Since 1990, voluntary local groups have been established to notify local authorities of Regionally Important Geological and Geomorphological Sites (RIGS; (Figure 64)). These RIGS groups have grown rapidly and today exist in all English and Welsh counties. Such groups are also being established in Scotland and Northern Ireland. The work of RIGS groups often involves museums, county wildlife trusts, industry and local authorities, as well as local geologists.

Although RIGS have no statutory status, they can be protected in a most effective way through local initiatives. Local authorities respond positively to protect sites that attract local support and will often accommodate their protection within Local and Structure Plans.

The need to protect Earth heritage sites other than SSSIs reflects a number of factors, particularly the demand for educational sites arising from an increase of interest in the Earth sciences. Other Earth heritage sites, with strong aesthetic rather than scientific appeal, are not specifically protected as SSSIs, but are valuable as a stimulation to raising public awareness and appreciation of geology and geomorphology. If such sites are of local, rather than national, importance, they may be protected by RIGS schemes. Many geological sites are also of local interest and importance for their flora, fauna, archaeology, mining history or amenity value, and they too may be protected as RIGS.

The network of RIGS groups helps to ensure that RIGS are accessible and, where appropriate, protected. The RIGS scheme nationwide is of great importance and complements the Geological Conservation Review.

Earth heritage site protection

The legal framework

The *Environmental Protection Act 1990*, the *Natural Heritage (Scotland) Act 1991* and the *National Parks and Access to the Countryside Act 1949* enable the statutory conservation bodies and local authorities to establish and manage, respectively, national and local nature reserves for the conservation of wildlife and Earth heritage features. Land can be bought or leased for the purpose, or contractual agreements can be reached with the owners and tenants of the land to ensure its protection and proper management. The 1949 Act also enables these bodies to make bylaws to protect the reserves from any type of damage. As a last resort, the statutory conservation bodies and local authorities have a power of compulsory purchase.

Over the years a number of Earth heritage nature reserves have been established, such as Wren's Nest National Nature Reserve near Dudley, in the West Midlands, which was secured as an NNR in 1956 (the first in the United Kingdom for geology; (Figure 65)). The founding of the reserve is in recognition of the exceptional international importance of the site as a source of Silurian-age fossils. The site has yielded a great variety of fossils in a superb state of preservation, the best of which can be found in museums throughout the world.

However, the 1949 Act recognised that it would be a long time before all important wildlife and Earth heritage sites could be acquired as nature reserves, if ever, and so it also contained a provision for the Nature Conservancy (and its successors) to notify local planning authorities of important areas, not yet managed as nature reserves, as SSSIs. Once a local authority is notified of an SSSI in its area, it is able to protect the site from adverse development under the controls provided by the Town and Country Planning Acts.

Individual planning decisions are guided by the Structure, Unitary and Local Plans relating to the area under consideration. Of particular relevance are mineral and waste disposal Local Plans.

As well as enabling applications detrimental to conservation interests to be turned down, the Planning Acts permit conditional consent to be granted. Such consents allow development to proceed on or near an SSSI with adequate safeguards to avoid damage to the important wildlife or Earth heritage features of the site.

Planning legislation (*Town and Country Planning Act 1990* and the *Town and Country Planning (Scotland) Act 1990*) also enables local authorities to enter into agreements with developers about how their land should be managed when development has taken place. These agreements are often negotiated in parallel with the consideration of planning consent. An agreement could, for example, require the developer and any subsequent owner to provide access to a geological exposure for educational or research purposes. If access had been restricted previously, such an agreement could be very beneficial.

The Planning Acts, and their associated General Development Orders, require local authorities to consult with the statutory nature conservation bodies before consenting to a development proposal affecting an SSSI. Various other statutes place a similar requirement on a range of statutory bodies and public utilities, including the water companies and the National Rivers Authority.

In addition, the *Wildlife and Countryside Act* strengthened the protection afforded to SSSIs considerably. This Act requires the statutory nature conservation bodies to inform all the owners and occupiers of an SSSI about the nature of the features of special interest of the site and of the types of activity that could cause damage to those special features. Before carrying out any of these activities, an owner or occupier must give the appropriate statutory nature conservation agency at least four months' notice. This enables the conservation agency to advise the owner or occupier how, if possible, the operation might be carried out without damaging the special interest. If that is not possible, a contractual agreement to protect the site may be negotiated. The financial provisions of such an agreement are calculated in accordance with national guidelines.

If an owner or occupier is determined to carry out a damaging activity, and this activity does not require planning consent, the Secretary of State may be asked to make a Nature Conservation Order which extends the period of notice. Such an Order also has the effect of making it an offence for a member of the public to damage the site.

The 1981 Act also contains a provision enabling a local authority to make a Limestone Pavement Order, on either landscape or nature conservation grounds, to prevent the removal of rock from limestone pavement areas.

Present legislation is proving to be legally effective. It is equally important, however, that all concerned work closely with owners and occupiers of important sites to promote effective conservation management.

Earth heritage conservation in practice

Conservation strategy

Once an Earth heritage site has been identified as worthy of special protection measures, a practical conservation management strategy needs to be developed and implemented. This strategy involves elements such as documenting the importance of the site, planning and implementing practical conservation and protection measures, site monitoring and site enhancement. Although developing site management strategies was not part of the Geological Conservation Review, such strategies are a necessary extension of it.

Classification of site types

There are two main types of site:

- Integrity sites contain finite deposits or landforms which are irreplaceable if destroyed. A typical situation is a glacial landform of limited lateral extent, such as a kame terrace or esker (*see* (Figure 35)). Other examples include presently active, and previously active, geomorphological sites (e.g. Morfa Harlech, (Figure 66)b), caves and karst, unique mineral, fossil or geological feature sites, and some stratotypes.
- Exposure sites provide exposures of a rock which is extensive or also well developed below the ground surface. Exposure sites are numerically the more common type and may include exposures in disused and active quarries, cuttings and pits; exposures in coastal and river cliffs (e.g. Hunstanton cliffs, (Figure 66)a); foreshore exposures; mines and tunnels; inland outcrops and stream sections. The broad conservation principles for these types of site are different. 'Integrity' sites are, by definition, finite and irreplaceable. To conserve them a more 'protectionist' approach must be adopted. In contrast, the broad conservation principle for exposure sites depends on the maintenance of an exposure, the precise location of which is not always critical. Quarrying may be welcomed under some circumstances

because it creates a fresh exposure and progressively reveals new rock surfaces, enabling a rock body to be analysed in three dimensions. Similarly, marine erosion is often vital in the creation of fresh rock faces at coastal sites, particularly in softer rock formations.

Conservation management of a geomorphological site depends on whether it is a relict landform or an active process site. Broadly, the requirements for the former will be similar to those for 'integrity' geological sites. The management of dynamic environments is, however, more complex, and requires an understanding of geomorphological sensitivity and the capacity of the system to absorb externally imposed stresses.

The consideration of the nature of the site as an 'integrity' or 'exposure' site helps a fundamental conservation principle to be developed: whether to protect the resource or maintain the exposure. Further general conservation principles can be added by considering the actual type of the site itself — whether it is an active quarry or coastal exposure, for example, where the likely threats, opportunities and problems are different. Finally, site conservation principles will need to take into account the precise location of the feature of special interest within the site. If a feature of interest lies at a cliff base in a quarry, conservation measures should ensure that the foot of the cliff is not obscured, but if the only feature is half-way up the rock face of the quarry, access to it may actually be improved if sand, shingle or other materials were to be placed at the foot of the rock face.

Using this framework of integrity/exposure site, site type, and the location of the particular feature(s) within a site, it is possible to draw up general conservation principles for different types of site, and provide guidance to conservationists as to the likely threats that may affect them. Building on this, a detailed series of guidelines, the Handbook of Earth Science Conservation Techniques (1990), produced by the NCC (now available from the Countryside Council for Wales, English Nature and Scottish Natural Heritage), describes conservation guidelines for more than 50 site scenarios. However, in order to draw up site-specific conservation plans which detail the measures essential to maintaining and conserving the interest of a site, and to identify the measures that would enhance it, detailed assessments need to be made at the site itself.

Practical conservation planning and implementation will involve the following elements:

1. Documenting the special interest of a site This may be done by reference to scientific literature, by discussion with experts and by direct observation at the site. For the Geological Conservation Review sites, the Review itself provides the firm foundation for the scientific credentials of a site, and site reports are ultimately documented in Geological Conservation Review volumes. Other documentation schemes are also in operation, such as the National Scheme for Geological Site Documentation, brief ly described in Record of the Rocks, that RIGS groups use for documenting RIGS sites, and provides a record of the geology at sites which can be used for teaching purposes.
2. Preparing a site conservation plan Information is required about what activities and processes would impair the interest at the site, how it would deteriorate naturally without intervention, and what action would be desirable, or even essential, to maintain the feature(s) of interest. The general scheme of conservation principles (integrity/exposure, type of site and location of the feature(s) at the site) can provide broad guidance. This will lead naturally to a consideration of what site-specific and practical Earth heritage conservation measures will be needed to ensure that the features of special interest are not obscured, destroyed or damaged, and also to indicate the recommended frequency of monitoring. The country conservation agencies are developing such plans for all Geological Conservation Review sites.
3. Safeguarding the site Site management involves:
    - periodic monitoring of the condition of a site so as to anticipate and identify the nature of degradation or damage
    - carrying out essential site safeguard measures, and desirable site enhancement operations, in response to the above, for example, site clearance or re-excavation should a feature become obscured.

In the examples below, potential threats at actual sites are described, and practical solutions to some of the problems that sites may face are indicated.

Earth heritage conservation in practice — some examples

Fossil and mineral collecting and conservation

The collecting of fossils and minerals is generally regarded as a benign activity which is an integral part of fieldwork. Many specimens are more valuable to science when removed from the rock than they are in situ, provided that they are collected in a responsible manner (*see* below), properly housed, curated and made available for use in a suitable museum. An example is an 'exposure site' such as a cliff face subject to erosion, where new fossils will be exposed continually as the cliff line retreats. In this case, the overall fossil resource can be very large, and it is important to collect and record the fossils before they are lost to the sea.

However, some rare fossil or mineral reserves are highly localised and only have a limited supply, such as an accumulation of fossil bones in a cave. At such 'integrity sites', irresponsible collecting can be very damaging. The conservation of such rare and irreplaceable sites in Britain is becoming increasingly important because they represent a finite, non- renewable resource. In many of these cases, conservation of the site will require that collecting is carefully managed to ensure that the maximum amount of information is gained and the site remains available for appropriate use in the future.

Palaeontological and mineralogical sites differ from many other Earth heritage sites in their management requirements, although they suffer the same potential threats as quarries, cliffs, mines or other outcrops. These threats may involve removal of the resource, or it being obscured by infill, afforestation, slope stabilisation or various types of construction. There is also the need to ensure that potentially irreplaceable material collected for research is properly stored and conserved.

The following guidelines constitute good practice.

- Obtain permission before collecting on private land, and respect the owner's wishes.
- Wear appropriate clothing and footwear. A helmet is essential if collecting near cliffs or quarry faces, and protective goggles if a chisel or hammer is used. Avoid collecting in dangerous situations. If collecting at the coast, consider tide times prior to the visit. Leave details of the collecting site, and your expected time of return, with a responsible person.
- Take only a few representative specimens, and if possible collect only from fallen blocks or loose stones — indiscriminate collecting will diminish the resource for future visitors.
- If removing a specimen from a rock face, make a careful note of its exact position in relation to surrounding rock; a photograph provides a useful reference. Label the specimen, giving details of where and when it was collected.
- If possible, remove a fossil complete with some of the surrounding rock, and protect it in paper or cloth for safe transport.
- Large fossils can be a problem for the individual collectors and could be left for others to see; otherwise seek advice from a local museum. Special equipment and lots of time may be required to excavate large specimens properly.
- Mineral collecting from old mines poses special problems — such as effects of stability of the old working or gas build up. Old workings should only be entered with an organised group and experienced leaders. Mine dumps can be visited with permission, however.

A leaflet published by the Geologists' Association is available about general conduct and safety on fieldwork.

The activities of collectors, including commercially oriented collectors, can unearth specimens which may otherwise not have come to light. Collectors should be encouraged to workwith specialists and museum curators so that every possible opportunity is taken to systematise their collecting and guarantee that material goes into a suitable repository. Irresponsible collecting may destroy an entire site, but is very difficult to control.

Coastal sites

Conservation of the Barton Geological Conservation Review site

The cliffs around Barton-on-Sea in Hampshire (*see* (Figure 9)) have been renowned for their Tertiary fossils for many years, and are still visited by many people each year. The site gives its name to a division of the Palaeogene sub-Period, the Bartonian Stage. The site is also nationally important for its Pleistocene Solent River Terrace Gravels.

Fossils are still abundant and are revealed by marine erosion. However, because of this erosion, the site has been under threat from coastal protection schemes on numerous occasions in the past. Previously proposed schemes of rock armouring, slope protection and slope grading, and the cutting of drains into the section, have already damaged parts of the site. Nevertheless, sections of natural cliff do remain, immediately east and west of the Barton frontage, although these could be obscured by the expansion of existing protection schemes.

Such exposure sites, susceptible to cliff fall, are often in conflict with engineering schemes seeking to prevent further erosion. Indeed, there is often intense local pressure to find engineering solutions to the problem of coastal recession. Coastal schemes commonly involve protective armouring (e.g. concrete sea-walls or rock revetments), which is often accompanied by cliff grading as well as drainage pipes and channels. In the extreme, such schemes can lead to the complete obliteration of the geological interest of the site. Alternative methods of coastal protection, achieving the objectives of reducing the level of marine erosion while limiting the impact of erosion on coastal cliffs of geological importance, have been investigated as part of an 'engineering for conservation' initiative.

In the Hampshire example it will only be through close co-operation between English Nature and the local authority that a mutually agreed action plan can be developed, which will afford protection to this world-famous and internationally important site, while at the same time addressing the problems of coastal erosion of local concern.

Active quarries

Conservation at Shap Granite Quarry

Shap Granite Quarry is a working quarry (Figure 67). The danger of falling blocks from unstable faces is brought about largely by the distinctive jointing pattern of the granite, whereby three sets of joints intersect to produce rectangular blocks, many of which are cut and used for decorative building stone. The rest of the granite is crushed and used for aggregates and pipe manufacture.

The quarrying company allows a limited number of parties to visit the quarry each year and these are usually directed to an area of prepared display blocks (Figure 68). The quarry face can be seen easily from the display area, but close access is not permitted. The blocks have been carefully selected to show all the features of the granite and its mineralisation and guarantee a selection of the characteristic 'pink' and 'dark' varieties of Shap Granite, unusually zoned minerals, a variety of veins and surface mineralisation. Weathered blocks, illustrating granite decomposition, as well as some specimens from the nearby Blue Quarry, are also on display.

The blocks provide an excellent selection of rocks and minerals which may otherwise not be available on any one visit to the quarry, because working quarries can uncover and then lose interesting features very rapidly. Thus the display represents an excellent way of maintaining the geological and educational interest of the site, while ensuring safety to the public.

Alternatively, agreements can be made with a quarry owner that one exposure face should be available for study as rock extraction progresses, and that a final face should be left intact when quarrying ceases. The precise location of the exposure is not critical in cases where the special interest lies in the rock type which is present throughout a quarry. By 'smooth blasting' the face, rather than production blasting (which is used for normal extraction and tends to leave remaining rock faces shattered), it is possible to create a stable and safe exposure of the rock for study. When extraction in the quarry is to cease, it is expected that a 'final' exposure will be agreed with the quarry owner and that this would be maintained as a permanent location of interest. This would be subject to the disused quarry considerations outlined below.

Disused quarries

Conservation at Ercall Quarry, Shropshire

The large area of hillside outcrop at Ercall is fairly safe from many of the common threats such as dumping, building construction and afforestation. The site includes a disused quarry (Figure 69), an exposure site. As a result of the cessation of quarrying activity, operations that were considered to constitute 'normal working practice' for mineral extraction are now considered damaging to the SSSI. For instance, activities such as the construction or removal of roads, tracks, walls or ditches, the laying or removal of cables or pipelines above or below ground, and the building of temporary or permanent structures were not considered a threat to the site during the period of active working. However, after active mineral extraction has finished, these operations are possible threats to the remaining exposure.

General considerations at disused quarries

At Kirtlington, Oxfordshire (Figure 70), the removal of slumped material that may obscure the lower rock layers may be desirable. Some of the material may, however, be a useful platform for access to higher sections, and it may also provide a resource for sample collecting. In softer sediments, where rock debris may accumulate at the quarry cliff foot, thus obscuring substantial parts of the exposure, it may be advantageous to create a 'stepped' face (*see* (Figure 71)).

Should a face like this become vegetated, it may be necessary to clean it every few years, although other conservation interests will need to be balanced. For example, a vegetated face may become a valuable nature conservation resource for other reasons, such as butterflies in abandoned chalk quarries.

Other considerations at sites similar to this could include diverting water run-off away from the rock face of interest, or adding a drainage system nearby to prevent flooding at the base of the face which would impede access. Such exposures may also need to be stabilised, by removing loose rock from a selected area (perhaps by pneumatic breaker or smooth blasting) or by adding supportive mesh or rock bolts to higher sections (if impairing access is not a problem). Any remaining dangerous areas could then be fenced off.

There may also be problems related to fly tipping in disused quarries, and vehicular access to the quarry edge may need to be impeded, perhaps by placing boulders to make a barrier.

Disused quarries as landfill sites

The main threat at the end of the working life of any quarry is subsequent use as a landfill site. However, despite the impacts of landfill, a sympathetically designed scheme incorporating geological exposures can provide an opportunity for the long-term conservation of important faces. M. J. Carter Associates provided an assessment report for the Nature Conservancy Council on the stability of refuse slopes. From this work a number of options have been identified for conservation within landfill sites (Figure 71). For example:

contouring the landfill material around geological faces creating reinforced earth walls around a geological face making alternative exposures by digging a face outside the proposed landfill site.

Stability, drainage, leachate and landfill gas are the main considerations and cost will play a large part in the choice of the preferred option.

Cave conservation

Caves (and associated karst sites) can be regarded as 'integrity' sites, because the features of interest are often irreplaceable (Figure 72). The broad conservation approach is therefore based on protection. The inaccessibility of some of these caves protects them to some extent. However, some very good localities have been lost or damaged because of caving activities, quarrying or collection by amateurs or professional dealers. Other activities can also be highly damaging if unmodified, such as effluent disposal and dumping, and entrance closure. Damage from changes in agricultural practice, water abstraction from boreholes and recreational caving can usually be avoided if the activity is sensitively planned and carried out. The use f specific cave conservation plans is one method of addressing the threats to cave sites.

As well as their importance for geology and geomorphology, caves are also important for their archaeology and fauna and flora; for example, they provide important hibernacula and breeding sites for several species of bat. In developing conservation plans for caves, the requirements of each type of interest will need to be balanced.

Issues of safety will be of the utmost importance for geologists studying cave sites, and the National Caving Association (NCA) code of conduct should be followed in this regard. The NCA has also published a National Cave Conservation policy (1995) in association with the statutory conservation agencies, and it describes in detail the issues concerning the conservation of caves.

Road construction

Conservation of Claverley Road Cutting

In the process of road construction, geological features may be threatened if, for example, a cutting is to be made. On the other hand, this process may also create an exposure where there was none before. The conservation principles and practice here will depend on the net effect of creation against removal. The Claverley Road Cutting is an example of a man-made inland exposure site (Figure 73). As a road cutting, the face needs periodic monitoring to determine its stability.

The site is not subject to any immediate threats but vegetation may obscure rock faces over a period of years.

At some road cutting sites, stabilisation is provided by rock bolts which help to maintain friction between adjoining blocks of rock. Drains, which divert water from the top of the section, may also be installed to help stability (as water running between blocks would lead to high water pressure, and so cause slippage).

The issue of safety for people examining the rock faces at road cuttings is important when considering the open access to such sites, particularly on busy roads. Regular monitoring of road cutting sites by local authorities ensures that they are safe. A number of recent publications encouraging good practice and a wider awareness by site users appear to have been effective in reducing the incidence of damage, such as that caused by rock coring.

Site excavation and specimen curation

The excavation in Brighstone Bay, Isle of Wight

After the initial discovery in 1992 of dinosaur bones weathering out from the cliff face at Brighstone in rocks called the Wessex Formation, funds for excavation were obtained from English Nature and the Curry Fund of the Geologists' Association. The initial dig lasted about a month and enlisted much local help (Figure 74). Approximately 30% of a medium-sized dinosaur skeleton was carefully exposed, numbered, plotted, photographed, plastered and transported back to the museum premises on the Isle of Wight.

Conservation of active geomorphological process sites

Conservation of the River Dee:a mobile meander belt

The River Dee (Figure 75) is one of only a few, large rivers with a well-developed, mobile meander belt in its lower course that is relatively free from direct human intervention. The pattern and scale of the meanders at this site are exceptional. Tortuous, double-horseshoe meander bends are sustained over a relatively long distance between Holt and Worthenbury. There has also been considerable channel change by meander migration and cut-off during historical times. This can be clearly seen on old maps of the area which show the English–Welsh border as it followed the river along a completely different course.

This locality includes both active and static geomorphological features of scientific importance in its active and abandoned channels (palaeochannels). By studying rivers like the Dee, a clearer picture of erosion and deposition processes, and meander development, can be gained, which can be important in understanding how rivers modify the landscape through time.

The main objectives in conserving this site are to maintain the fossil landforms (the valley, various ancient river cliffs, palaeochannels and abandoned meanders) in as natural a state as possible, and to allow the presently active natural processes of erosion and deposition of sediment to continue with minimal intervention, thereby allowing the channel to undergo natural changes which include meander migration. The boundary of this site is therefore sufficiently large to allow for future river channel changes.

Potential threats include river management works, such as bank maintenance, the construction of f lood defence structures and floodwater management, which prevents the natural development of the floodplain. There is some evidence to suggest that the meander belt is not as active as it once was, which may be the result of river management upstream, particularly the regulation of discharges.

Large-scale river management works, which either modify the meanders or completely stabilise parts of the reach, must, therefore, be viewed as highly undesirable. In both a morphological sense (the alteration of the shape or form of the landforms) and a dynamic sense (having unquantifiable effects downstream in terms of erosion and deposition).

Mine dumps

Writhlington Rock Store SSSI

Writhlington Rock Store was nearly buried as part of a landscaping scheme, but with the co-operation of British Coal, and assistance from the Curry Fund of the Geologists' Association and English Nature, a section of the spoil was left untouched. The rock contains rare plant and insect fossils from the Carboniferous Period, and the continued access to the material has encouraged a great many important finds to be made by professional palaeontologists and amateur collectors (Figure 76). These finds have significantly enhanced our understanding of the evolution and diversity of Carboniferous insects. The area is regularly turned by machinery to expose new spoil especially for collectors.

Site 'burial'

The deliberate burial of a site, which contains sensitive or unique material susceptible to weathering or over-collection, is another practical method of Earth heritage conservation. Similarly, it may be desirable to leave a site naturally covered by soil/vegetation (as is the case at the Rhynie Chert site, (Figure 46)). If the site contains sediment which is unconsolidated, natural vegetative cover may help to diminish the effects of weathering and erosion. In these examples the occasional excavation of the sites for research may be desirable.

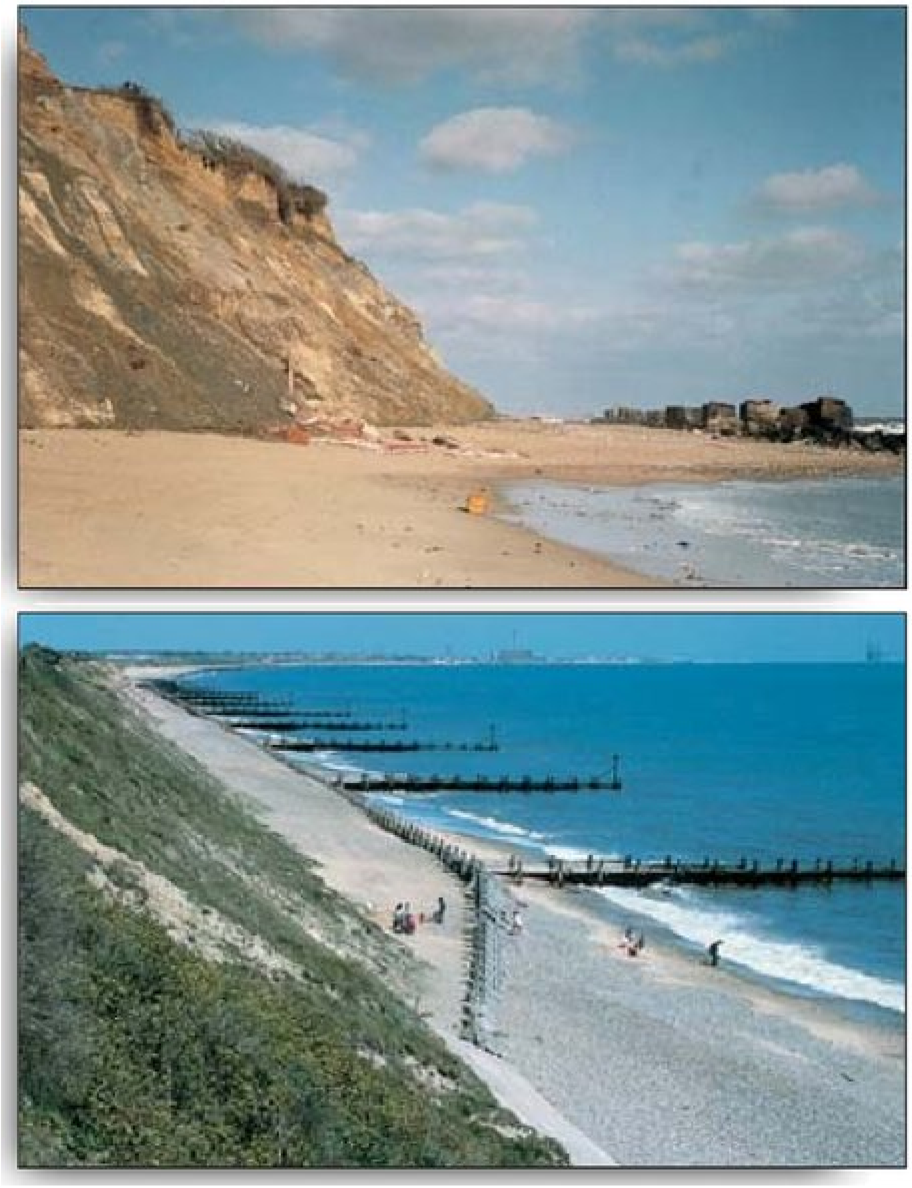
Publicity and public awareness

Achieving recognition of a site with regard to its importance to conservation is possible through education and site publicity. This is also part of conservation, as is encouraging the 'use' of the site for scientific research or education and training. This can be done in a number of ways, including erecting information sign boards on site (Figure 77), media publicity and producing books and leaflets about particular sites or groups of sites. Of course, SSSI status does not automatically imply open access to private land, however.

Advice on conservation of Earth heritage sites

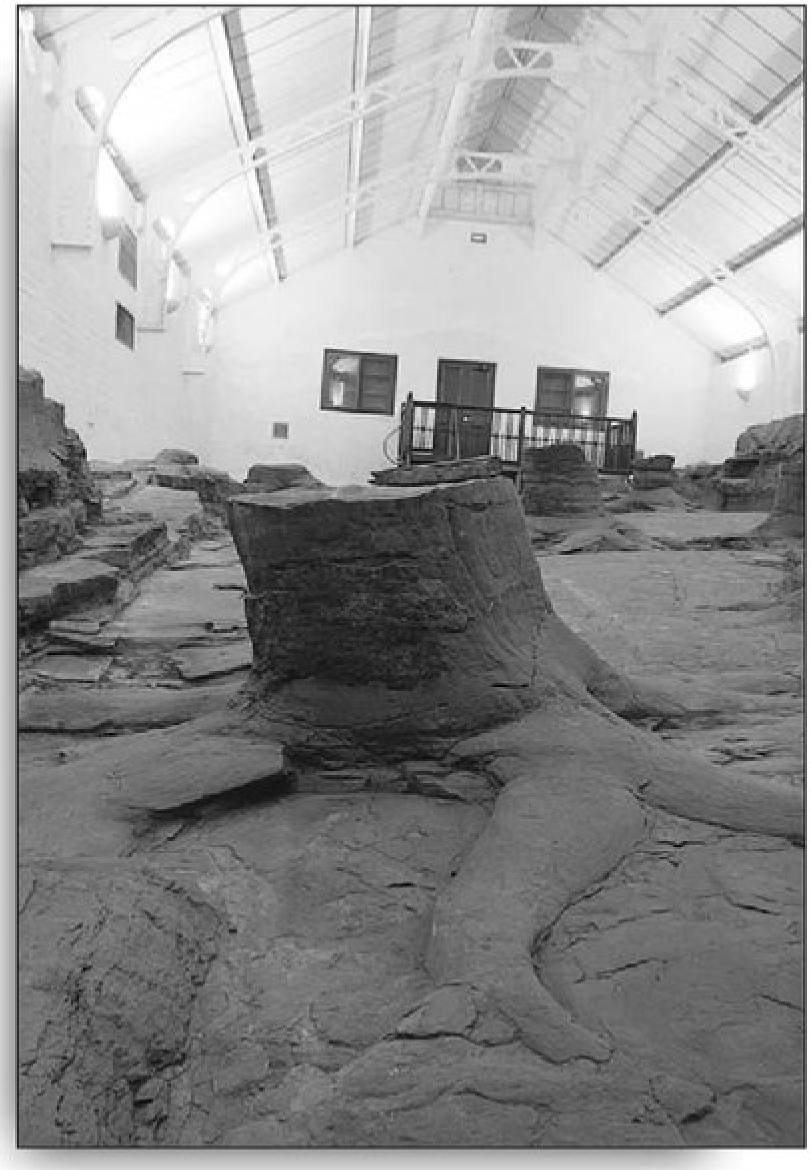
For Geological Conservation Review sites and SSSIs, local planning authorities, statutory bodies, potential developers and owners and occupiers should seek the advice of the appropriate local office of the relevant statutory nature conservation body before authorising or carrying out a potentially harmful activity at the site, or when planning any improvement to the site. The various offices of the bodies, and the areas they cover, are given in the Appendix to this book.

Further guidance on practical site conservation is given in A Handbook of Earth Science Conservation Techniques (the appendices to Earth Science Conservation in Great Britain — A Strategy).



[References and further reading](#)

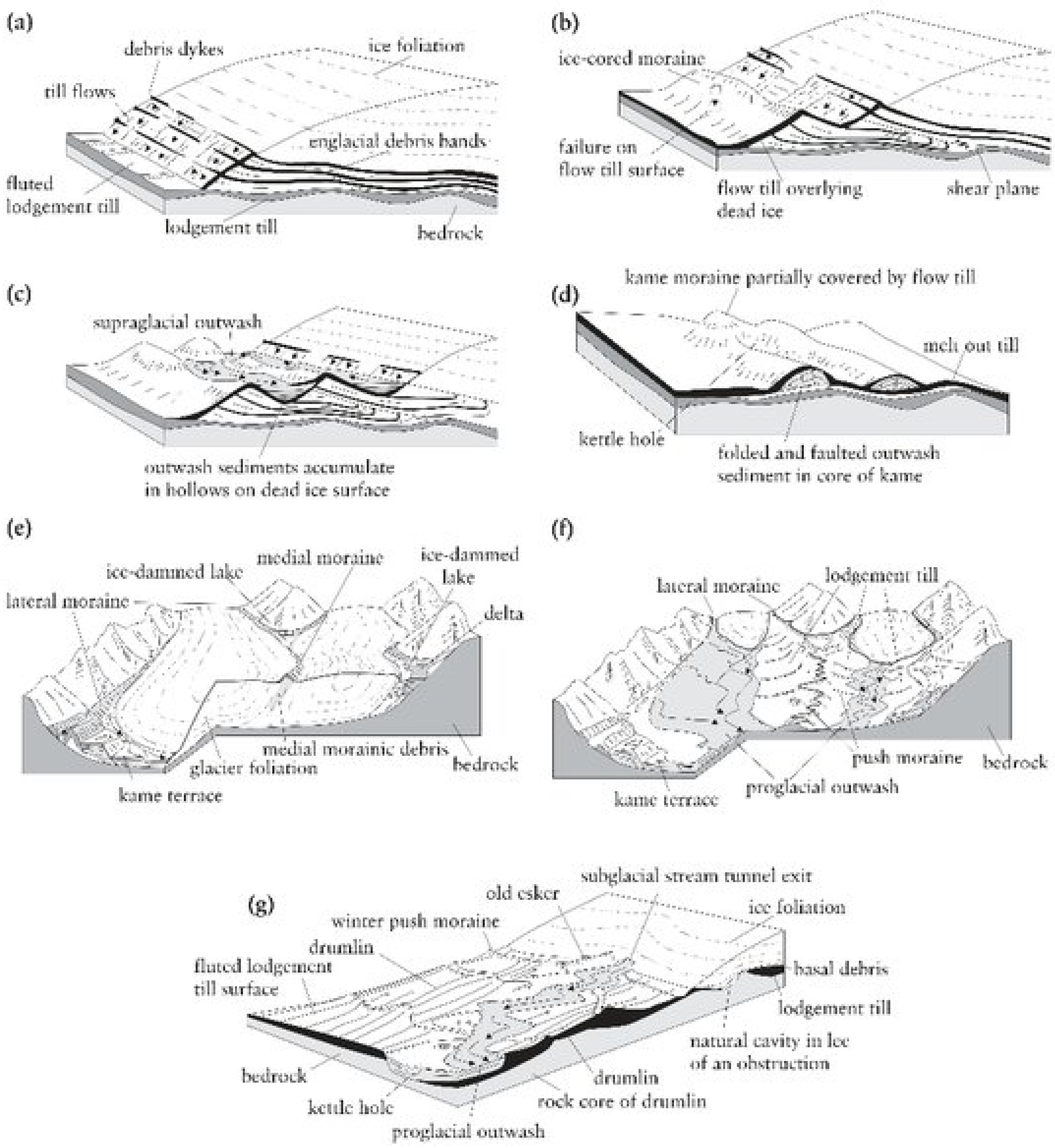
(Figure 62) Coastal defences at Corton Cliff, Suffolk. This site is important as the type section for the Anglian Stage (part of the Quaternary Period), during which the most extensive glaciation of Britain occurred. (a) The coastal section as it appeared in 1964, before modern sea defence works were undertaken. To the right lies the old sea wall, built in the late nineteenth century to protect a private estate. The wall remained intact until the turn of the twentieth century, indicating the extent of cliff erosion over 60 years. (b) The stabilised and vegetated cliffs at Corton. There are two types of structure forming the defence of the cliffs at this locality: a steel and concrete wall and a timber wave screen. Coastal protection works such as these may be in conflict with geological conservation, because for some sites continued erosion is necessary to renew exposures of rock. There is little geological interest in the vegetated slope without resorting to excavation work. Photos: Landform Slides, Lowestoft.



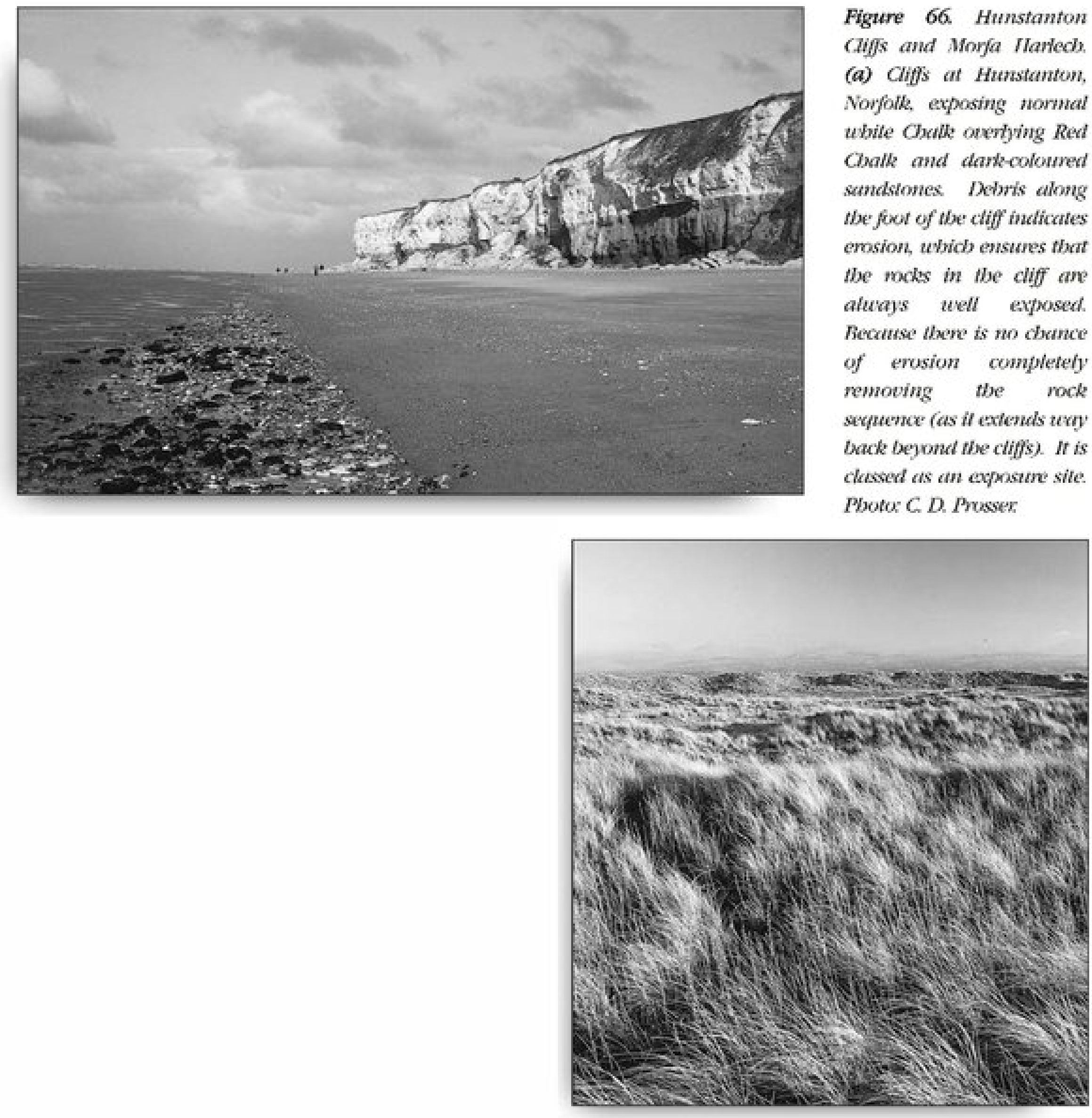
(Figure 63) Fossil Grove, Glasgow. Stumps of a once flourishing forest of lycopods. This tree-like plant grew in a tropical forest which covered this area of southern Scotland during the Carboniferous Period. The trunks, characterised by diamond-shaped leaf scars, grew up to 30 metres before they branched. Photo: A. Gunning.

(Figure 64) Coombs Quarry, Buckinghamshire: a RIGS. A collaborative effort by the Buckinghamshire RIGS group with the County Council Countryside Section and local geologists opened up and improved this site. This involved the clearance of the overgrown face, the creation of a new exposure, the provision of walkways and fencing, and the placing of boards with on-site interpretation. The geological interest of the site was first noted in 1860, during mapping by the Geological Survey. The rocks here, the Blisworth Limestone Formation, date from the Middle Jurassic, and are about 160 million years old. The nature of the different rock types and fossils of the rock beds are now accessible to study. Photo: L. Davies.

(Figure 65) The ripple beds at Wren's Nest National Nature Reserve in Dudley, West Midlands, viewed from the purpose-built observation platform. This visually impressive rock surface provides evidence for the environments of the Silurian Period. Similar ripple marks can be seen today on sandy beaches and river estuaries. Scree, at the base of the slope, continues to yield a wealth of fossils, including trilobites, for which Wren's Nest is particularly renowned. Photo: J. Larwood.



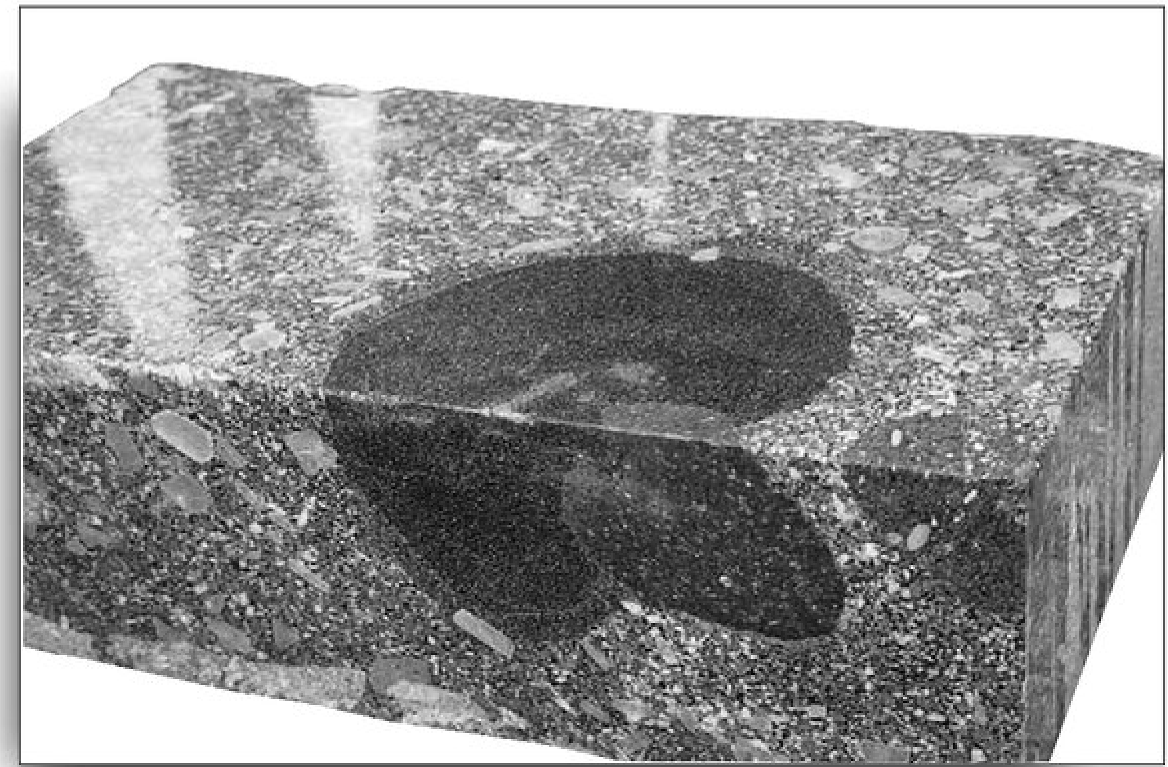
(Figure 35) Schematic diagrams showing the formation of glacial depositional landforms and deposits. (a) Flow tills form on the surface of the retreating glacier from thick sequences of englacial debris. (b) Till cover inhibits melting of underlying ice which is left behind during glacier retreat as an ice-cored moraine ridge. Supraglacial flow till is still active. (c) Outwash from the active glacier is forced to flow between ice-cored ridges and tills flow into the outwash systems. When the outwash dries up, the flow till forms a capping. (d) Dead ice melts, thus reversing the topography and leaving melt-out till in its place. The kame sediments show collapse structures. Such sequences are extremely common in lowland Britain. (e) and (f) Development of the features of a glaciated valley. The principal features are lateral and medial moraines and kame terraces. (g) The formation of the subglacial/proglacial sediment features. The till surface bears drumlins and on it are superimposed fluted moraine ridges; push-moraine ridges are associated with readvance of the glacier front, either in winter during a general retreat phase or in response to longer term cooling; lee-side till forms in a natural cavity where debris falls from the ice roof. Relatively rare eskers form in subglacial or englacial stream channels; proglacial outwash cuts through the till; kettle holes form in old outwash where stagnant ice blocks melt-out (the underlying sediments show collapse structures). A simple stratigraphy of outwash on till is produced by a single glacial episode of advance and retreat. After Boulton and Paul (1976).



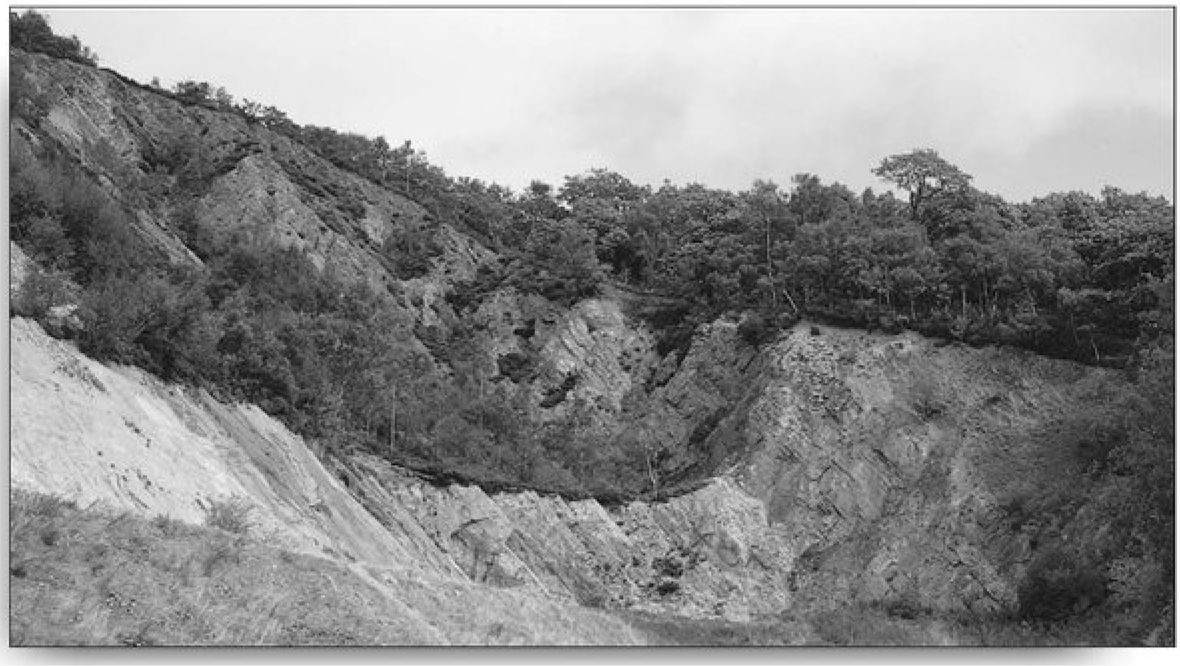
(Figure 66) Hunstanton Cliffs and Morfa Harlech. (a) Cliffs at Hunstanton, Norfolk, exposing normal white Chalk overlying Red Chalk and dark-coloured sandstones. Debris along the foot of the cliff indicates erosion, which ensures that the rocks in the cliff are always well exposed. Because there is no chance of erosion completely removing the rock sequence (as it extends way back beyond the cliffs). It is classed as an exposure site. Photo: C.D. Prosser. (b) Coastal sand dunes at Morfa Harlech, Gwynedd. These landforms would be destroyed by erosion or commercial extraction of sand. Therefore they need conserving, by allowing them to evolve naturally, and so they are an example of an integrity site. Photo: S. Campbell.

(Figure 9) Cliffs near Barton-on-Sea, Hampshire. The cliffs are made up of sediments deposited in marine, brackish and freshwater environments. Where these sediments occur inland, there are no natural outcrops, the land largely being built over or farmed, and there are few opportunities to see vertical sections through the strata. On the coast, however, fresh sections occur as the sea erodes the cliffs, but they can be obscured by coastal defence works and landslides. Photo: C.D. Prosser.

(Figure 67) The Shap Granite Quarry, Cumbria, showing regular jointing and the unstable face. This is an example of an exposure site. Photo: J.L. Eyers.

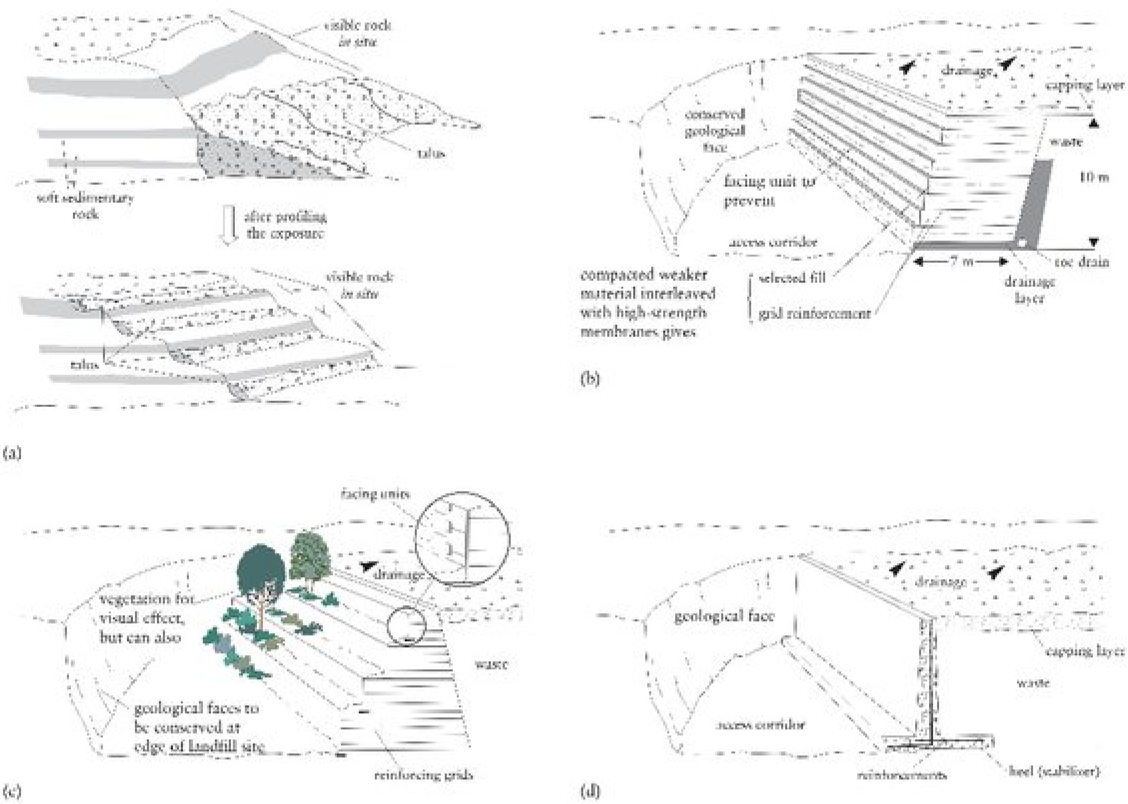


(Figure 68) Close up of a display block in the 'safe' area of Shap Granite Quarry. One of the main features of the granite is the large crystals of pink feldspar. These may have either developed at an early stage during magma cooling and solidification, or grown later in the solidified granite, during metamorphism. The nature of the dark fragments in the granite is also debated. Some believe that these are actually fragments of a darker magma which was present at great depth, and was intermixed with the paler granite by convection processes, engulfing some of the pink crystals en route. Others believe that the dark fragments were part of the surrounding rock which became engulfed and the pink crystals grew within them during metamorphism. Photo: J.L. Eyers.



(Figure 69) The disused Ercall Quarry in Shropshire displays the Vendian (end 'Precambrian')– Cambrian boundary. The steeply dipping beds are of Cambrian age. These beds contrast distinctly with the pale, non-bedded form of the Precambrian quartzite on the far left of the photograph. Photo: C.D. Prosser.

(Figure 70) The rock exposure at the disused Kirtlington Quarry in Oxfordshire is important for Middle Jurassic fish fossils. Photo: J.G. Larwood.



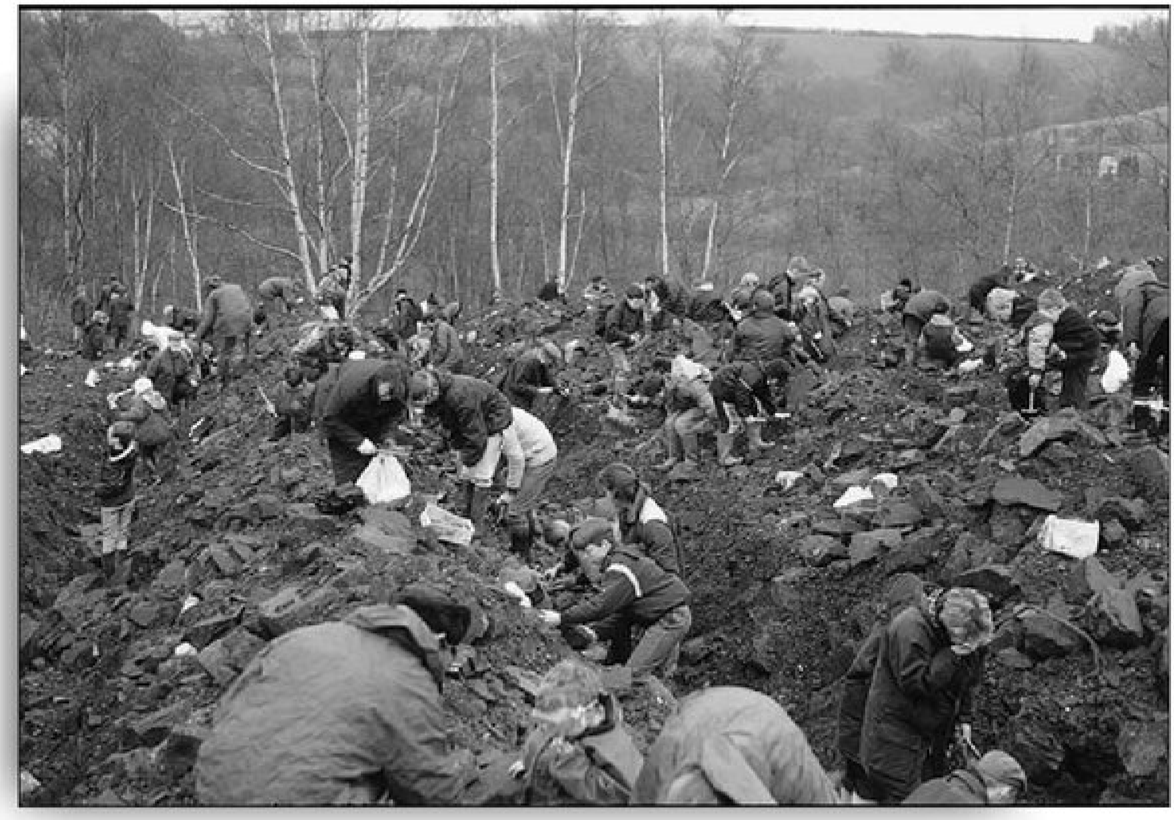
(Figure 71) (a) Diagram of a 'stepped' face in soft sediments which prevents the build up of all of the talus at the cliff foot. Diagrams (b) to (d) show idealised sections of conservation schemes within landfill sites.

(Figure 72) The spectacular, irreplaceable cave formations of the White River Series, Peak Cavern, Derbyshire. Photo: P.R. Deakin.

(Figure 73) Claverley Road Cutting, Shropshire. The site is important for the study of ancient river environments that existed in the Triassic Period. Photo: English Nature.

(Figure 74) Excavation of dinosaur remains at Brighstone Bay, Isle of Wight. The skeleton seems to be that of a sauropod dinosaur which died on a land surface that was subsequently inundated by flooding. The seemingly chaotic disarticulation and distribution of the bones could be explained by scavenging of the carcass prior to flooding. Photo: S. Hutt.

(Figure 75) (a) A river cliff of the outermost part of a meander of the River Dee, between Holt and Worthenbury. The shape of the meander continues to change as the cliff is eroded. Photo: S. Campbell. (b) Meanders of the Dee viewed from the air. Photo: National Remote Sensing Centre Limited (Air Photo Group).



(Figure 76) The rock piles at Writhlington Rock Store SSSI are an important source of plant and insect fossils. Photo: C.D. Prosser.

Figure 46. *Rhynie Chert. The site at Rhynie in Scotland is visually unimpressive, and may seem an unlikely geological location, but it is one of the most important palaeontological sites in Great Britain and the world. The Rhynie site contains some of the finest preserved and earliest land plants (Devonian) in the world. It also contains the earliest-known wingless insect* (Rhyniella) *and one of the finest Devonian micro-arthropod faunas in the world, including mites, springtails and a*

(Figure 46) Rhynie Chert. The site at Rhynie in Scotland is visually unimpressive, and may seem an unlikely geological location, but it is one of the most important palaeontological sites in Great Britain and the world. The Rhynie site contains some of the finest preserved and earliest land plants (Devonian) in the world. It also contains the earliest-known wingless insect (Rhyniella) and one of the finest Devonian micro-arthropod faunas in the world, including mites, springtails and a small aquatic shrimp-like organism, Lepidocaris. The fossils are preserved in chert. The deposit is an excellent example of the freak preservation of life resulting from the flooding of a marsh surface on which these plants were growing, by silica-rich water originating from a hot spring. The hot water killed and preserved the plants and animals before their tissues decayed, and so preserved a complete ecosystem. The arthropods found in the deposit are all primitive forms, and show an early association between plants and their parasites. Preservation is so good that microscopic damage to the plants by these arthropods is seen, as are invading fungal hyphae. The plants are preserved so well that thin sections of rock can be sliced, and examined under a microscope, to reveal the cell structure, including the minute detail of spores as well as cell xylem and stomata. The photographs show a sample and thin section of the chert. The thin section shows the mouthparts of a palaeocharinid (a spider-like arthropod). Photos: C.C.J. MacFadyen (chert sample) and N.H. Trewin (thin section).

(Figure 77) The sign board at Hunstanton, Norfolk. Photo: C.D. Prosser.