Geo Factsheet

www.curriculumpress.co.uk Number 148

LIMESTONE LANDSCAPES AND ECOLOGY IN THE UK

What is limestone?

Limestone is principally an organic sedimentary rock, which covers approximately 7% of the world's land surface. Limestone is made up of more than 50% (by weight) of calcium carbonate ($CaCO_3$), much of it in the form of fragments of fossil shells. Other types of limestone are also found: 'chemically precipitated' and 'detrital', but in terms of UK landscapes these are of lesser significance.

Organic limestones are often classified according to their texture and the nature of the organisms incorporated, e.g. oolitic limestone, shelly limestone, algal limestone and crinoidal limestone.

Limestones have been formed at different times during geological history. The classic limestone landscapes of N. Yorkshire and the Pennines are dominated by Carboniferous limestone, which is one of the most resistant.

Limestone Glossary

Aquifer *A rock that stores and transmits water in significant quantities – limestone is a good example.*

Clint *A block of limestone on a limestone pavement bounded by open grikes.*

Doline *A small to medium sized closed depression, a few metres to a few hundred metres in diameter and depth. Dolines are formed by slow, concentrated solutional removal of rock in an area, from the surface downwards, or by the collapse of overlying rock into a cave or chamber beneath (collapse doline). Dolines function as water funnels, allowing point recharge of the karstic aquifer. They are also termed sinkholes and swallow holes.*

Dolomite *Carbonate rocks which have undergone chemical changes resulting in the replacement of some of the calcium by magnesium. Can be highly karstified in places.*

Grike *A fissure (crack or joint) in the limestone bedrock that has been widened, sometimes to tens of centimetres, by the dissolving action of rainwater.*

Karst *An area of limestone or other highly soluble rock, in which the landforms are of dominantly solutional origin, and in which the drainage is usually underground in solutionally enlarged fissures and conduits.*

Limestone Pavement *Bare limestone surface from which soil and loose rocks have been stripped – usually by relatively recent ice erosion during a glacial period.*

Solution *The process by which limestone is dissolved, mainly by the acidity (both natural and human-induced) of precipitation.*

Stalactite *The mineral calcite (calcium carbonate) deposited in crystalline form from lime-rich dripping waters on to the roof of a cave. Stalactites grow downwards to form tapering pendants.*

Stalagmite *Calcite deposits as per stalactites but with the deposition taking place where trickles of water splash on to the cave floor. The resulting deposits grow upwards to form a column.*

Karst in the Landscape

The nature, occurrence and distribution of limestone may have a range of influences on the landscape:

- ***Karst limestones are important sources of water*** – large springs (suitable for drinking water) can emerge from karst scenery. Limestone may also support aquifer stores for potable (drinking) water.

- ***Karst limestone presents special concerns for engineering.*** Due to its irregular surface, large voids and rapid underground drainage, karst landscapes often present complications from an engineering perspective. Projects such as roads, bridges, tunnels and mining require careful site investigations and contingency for unseen problems.

- ***Limestone landscapes provide abundant resources for quarrying and mining activities.*** The nature of limestone means that it can be used as the raw material for cement manufacture; limestone is also used as a building stone and as a sulphur dioxide 'cleanser' in many industries, e.g. coal-fired power stations. Fluorspar and lead are commonly mined in limestone areas.

- ***Agriculture*** – limestone (calcareous) soils support a rich turf-like cover of grass. This short grass is ideal for sheep grazing.

- ***Karst environments support a distinctive ecology.*** These unique ecological environments are often under threat from human activity, in particular, farming, urban development and removal of limestone for rockeries.

- ***Karst landscapes are important for archaeology, heritage and tourism.*** The distinctive upland landscape is a major tourist attraction; in many areas, e.g. Northern Ireland, prominent hills of karst limestone provide some of the UK's best known archeological sites. Over and underground karst features may also relate to the historical site and situation of settlements and other types of land-use. The unusual and spectacular features in karst areas such as gorges and limestone pavements are attractive to tourists.

Exam Hint: *Rewrite this list and add examples of each activity.*

A note on KARST

*The term **'karst'** is normally used to refer to the classic limestone features – see Fig. 2. The term **karst** derives from the Slovenian word **kras**, meaning crag or stony ground, especially bare rock surfaces. Technically however, karst is terrain with distinctive landforms and drainage arising from greater rock solubility in natural waters than elsewhere.*

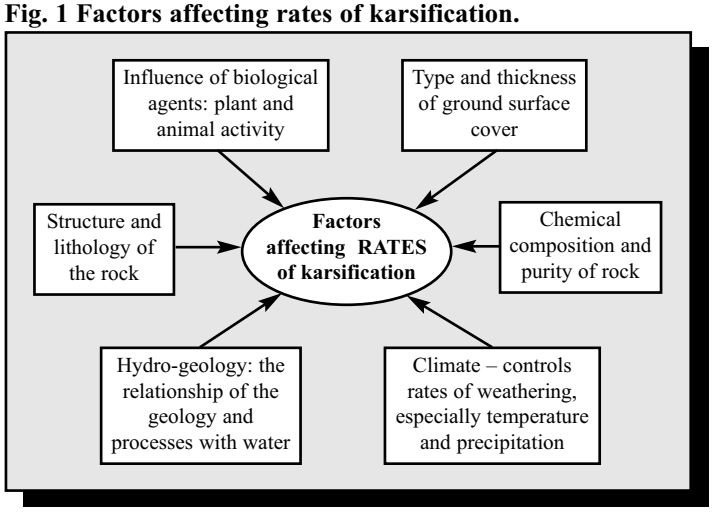
Most of the distinctive landscape elements of limestone reflect solutional enlargement of the internal joint systems. Limestone is formed in layers – **bedding planes**. These bedding planes contain vertical cracks called **joints**; it is the joints and planes that make limestone **permeable**. The term **pervious** is used to describe this type of permeability. Solutions move through the spaces and dissolve calcareous material which is soluble in water. This subsequently enlarges the cracks and joints, creating subsurface / underground waterways and caves. At some points the underground waters return to the surface as springs. About half of the limestone solution occurs below ground.

Solution of limestone

Carbonate (limestone rocks) consist of two stable minerals, calcite and dolomite which are both soluble in natural water containing dilute carbonic acid. Carbonic acid occurs naturally (the reaction of the CO_2 from the air with water), but there is concern over human-induced acid rain which is the by-product of many modern processes, e.g. combustion of fossil fuels.

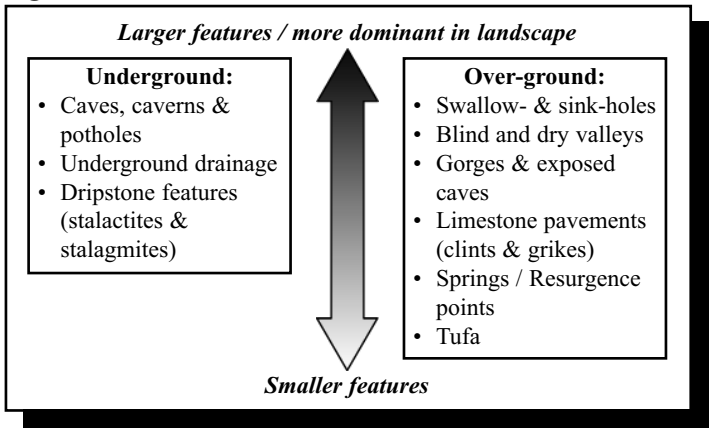
The nature of the limestone strongly influences its susceptibility to **karsification** *(Fig. 1)*. 'Purer' limestones tend to be more brittle, allowing extensive open fractures, whilst impure forms (shaly limestones) tend to deform more readily, sealing up fractures and impeding water movement.

Fig. 1 Factors affecting rates of karsification.



In nearly all branches of landform study, classification is difficult because one form or process tends to grade into another. However, one way of classifying dominant limestone features is to describe them according to whether they are found **above** or **below ground**. *Fig. 2* classifies karst features.

Fig. 2 Classification of limestone features.

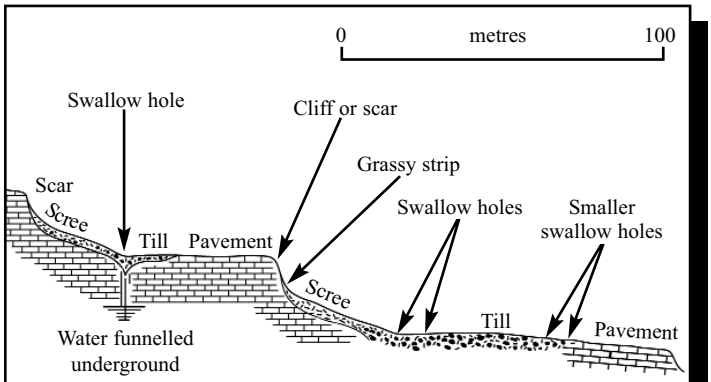


Development of limestone features

- **Overground / Surface features:**

There is enormous variety in the nature and scale of surface karst features. They range in size from just a few centimetres (e.g. pitted weathering-surfaces called 'karren') to massive features which dominate the scenery. *Fig. 3* shows the landscape features of a typical limestone hillside. The list below refers to the larger and more widespread karst landscape features:

Fig. 3 Landscape features of Askrigg Block, N. Yorks – a typical limestone hillside.



Note: The swallow holes result from the subsidence of glacial till. They are also known as sink holes.

1. ***Swallow and sink-holes.*** There are many different kinds of stream sinks or closed hollows (also known as 'dolines'). These are the fundamental features of karst scenery, essentially replacing 'normal' river valleys associated with a fluvial terrain. Often, the surface of the limestone is pitted with deep hollows, conical or saucer shaped, and sometimes hundreds of metres deep and several kilometres in diameter. These depressions act as funnels, collecting surface drainage and leading it into underground cave systems.

2. ***Dry or blind valleys.*** These result from the loss of water into streamsinks either at one point, or at successive points along a channel. Gradual diversion through the sinkholes can lead to complete diversion of the stream underground. This means that surface rivers are usually few in karst areas. Dry valleys provide evidence that the river once flowed above the ground surface, at times when the joints and fissures in the rock were essentially impermeable (they might have been frozen with ice in a periglacial environment). Following de-glaciation, the water was able to drain into the rock, leaving a dry valley.

3. ***Gorges***. Although gorges are found in many different rock types, they tend to be more frequent and dominant in karst landscapes. Gorges are steep sided valleys, formed when the roof of an underground cave collapses. Gordale Scar (N. Yorkshire) and the Cheddar Gorge (Somerset) are two of England's best known gorge features.

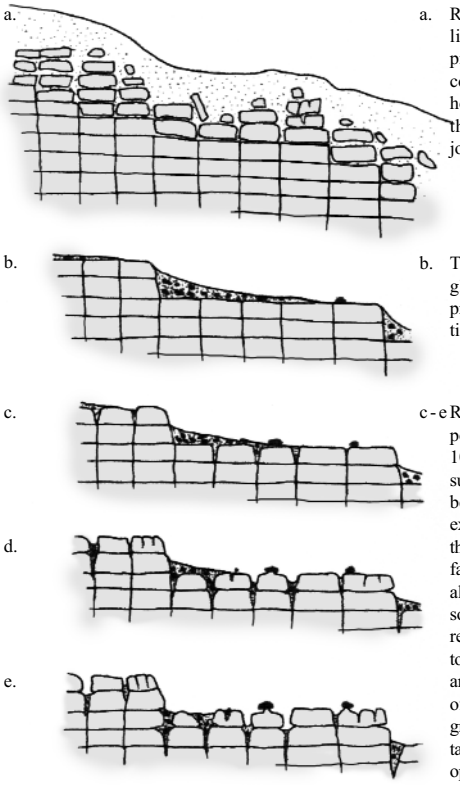
4. ***Springs and resurgence.*** Water draining through limestone commonly emerges in streams from caves, or as upwelling springs. As water can circulate beneath the water table, sometimes the resurgence has high volume and velocity.

5. ***Tufa.*** A feature of some stream channels is the formation of calcite damns across channels. The calcite is called 'tufa' and is precipitated because CO_2 is lost from the stream water, or calcite is secreted by some mosses and algae. Tufa barriers can cause natural bridges, rapids or waterfalls.

6. ***Limestone pavements.*** Limestone areas are often high and flat, due to the underlying horizontal bedding planes. If the top soil / surface regolith is removed, for example as a result of glaciation, then the top bedding plane will become exposed and subject to solution. *Figs 4* and *5* show the evolution of limestone pavements and characteristic morphology.

Fig. 4 Theoretical formation of a limestone pavement.

There is still no firmly accepted theory for the evolution of limestone pavements, but the recognised model describes formation according to the sequence below.



a. Represents a pre-glacial limestone landscape, protected by a thick covering of regolith. Note how the upper surface of the limestone is heavily joined and fractured.

b. This is the immediate post-glacial form, partially protected by a thin layer of till and regolith.

c - e Represent changes in the post-glacial period (last 10,000 years). The upper surface of the limestone has been heavily weathered – exposed to the solution and the action of rainwater. The fact that it is bare means it is also liable to frost action, in some cases aided by pressure release jointing. This has led to the development of **clints** and **grikes**. Clints are blocks of limestone, bounded by grikes, whereby solution has taken place along joints to open up clefts, sometimes 1-2m wide.

Fig. 5 Different types of limestone pavement.

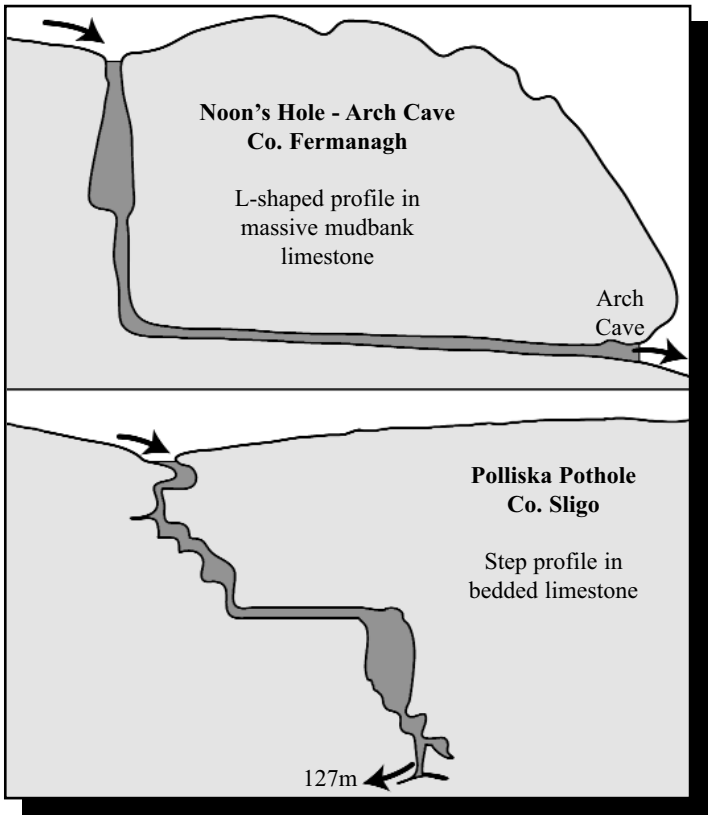
a. Broad tabular clints separated by narrow grikes. Solution has been limited because of little or no drift/till cover.

b. Narrow clints and grikes – the result of closer jointing and more intensive solution.

- **Underground features:**

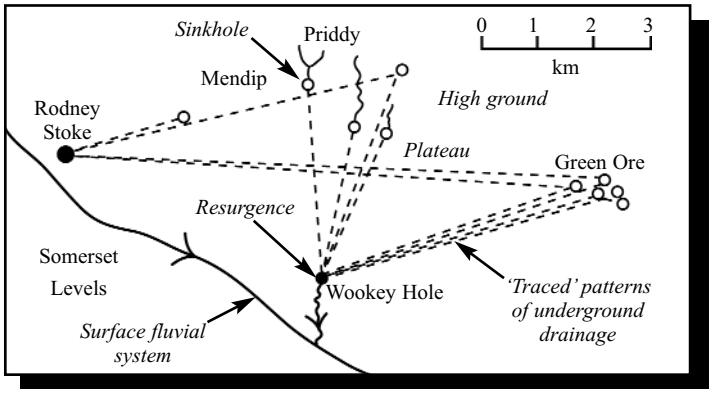
1. ***Caves, caverns and potholes.*** Limestones vary in capacity to contain caves because of their chemical composition and mechanical strength. Caves can vary in size from just a few metres to many hundreds of metres; they also vary in profile and form – *see Fig. 6.* Caves are formed as the space created by limestone solution becomes larger with time.

Fig. 6 Influence of limestone type on cave profiles in NW Ireland.



2. ***Underground drainage.*** Water tracing can be used to determine lines of underground drainage – this reveals an unusual phenomenon that cannot be matched by surface systems - namely independent lines of flow at different levels crossing one another without interference. *Fig. 7* shows an example of this from the Mendips.

Fig. 7 Surface and underground drainage in the Mendips, S.W. England. ***Note independent lines of flow crossing one another without interference.***



3. ***Dripstone features.*** When cave passages are abandoned by the streams that once created them, drips of water from above may deposit crystals of pure calcium carbonate (calcite) which gradually form calcite deposits, e.g. stalactites (hang down), and stalagmites ('grow' up from the floor of a cave).

People and Limestone Landscapes

In areas where karst scenery dominates, there may be evidence for human impact:

- The dominance of limestone scenery may also exhibit an effect on local building styles and materials. Although structurally relatively strong, limestone is very susceptible to attack by acid rain. Portland limestone was used to build the Houses of Parliament and St Paul's Cathedral. You can see the impact of chemical damage.
- Tourism is an important aspect of many limestone areas. It boosts the local economy, providing much (but often seasonal and low paid) employment. In Ireland, for example, the upland karst regions such as the Burren, the Aran Islands, Ben Bulben and the Cuilcagh mountains have particularly attractive scenery. Many caves systems are open to the public, including the Marble Arch Caves in Co. Fermanagh. The caves have recently been awarded 'Geopark' status.

Geopark Status

The European Geoparks Network was established by the European Commission in co-operation with UNESCO to protect the geological heritage of Europe and to encourage sustainable development based on geo-tourism. The Geoparks initiative is designed to supplement UNESCO World Heritage Sites and recognises European sites that are of international importance for their geology, landscape and educational value.

- Quarrying in karst areas often causes a conflict between the economic advantage of extracting the valuable raw material (and providing local employment), and the loss of landscape, amenity, noise, dust and extra traffic. *See Case Study 1 below.*

Case Study 1: Quarrying in Castleton – The Hope Valley Cement Works

The Hope Quarry and Cement Works is the largest employer in this part of the Peak District, with over 300 people directly working for the Blue Circle Cement Company (90% of whom are locals). The uses of the limestone from the Peak District are shown in the table.

Aggregate (roadstone etc)	56.0%
Cement	23.0%
Chemicals	17.0%
Iron and Steel	4.0%
Agriculture	0.2%

The cement works was founded in 1929 and now produces about 1.3 million tonnes of cement a year. This is about 10% of the British supply. To produce this, the cement works uses 1,730,000 tonnes of local limestone and 305,000 tonnes of local shale. About 40% of the cement is transported by road and the remaining 60% by rail.

Mines and quarries often have to justify their existence based on the following ideas:

1. *Is there a real need for the product, either locally or nationally, or could another product be used instead? i.e. stone other than limestone can be used for roads.*
2. *Is there another source for the material that would be a practical alternative? i.e. limestone can be found in other parts of the country that are not National Parks.*
3. *What will be the effect on local traffic? Can the local infrastructure cope with increasing heavy goods vehicles? Moving stone by railway may be a possible alternative.*
4. *To what extent will the local residents, landscape and environment be affected? The Park Authority now insists that landscaping schemes and restoration work must be agreed as part of any new proposal.*

- Population densities are often low in limestone areas. This is partly controlled by relief and topography, but perhaps more significantly the lack of surface water due to the permeable nature of the limestone. Settlement distribution tends to be dispersed and the settlements themselves nucleated. Where settlements have developed it is often close to sources of water, i.e. resurgences, leading to the growth of 'spring-line villages' known as wetpoint sites. The villages surrounding Shepton Mallet, near the Cheddar Gorge in Somerset provide examples of this effect. Malham in the Yorkshire Dales is also located on a spring in the Malhamdale area.

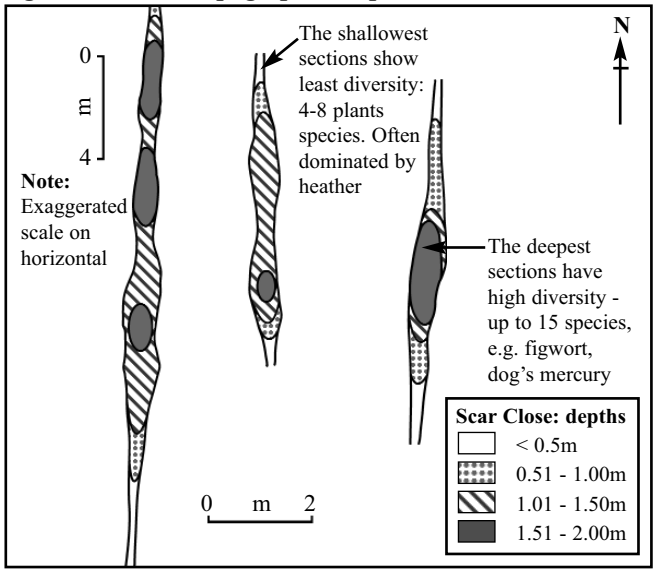
Ecology

Limestone areas, in addition to having high amenity, economic and recreational value, are also valuable ecological habitats. The vegetational structure, diversity and quality may be controlled by a number of factors: rock lithology and structure, soil type and cover, climate, and probably most important the influence of people, namely land-usage and grazing pressure. Of all the surface karst landscape features, limestone pavements are a particularly sensitive and valuable ecological habitat: hence many of them have designated ecological status (NNR or SSSI) in order to protect them.Globally limestone pavement is a scarce and non-renewable resource. The area of British limestone pavement is small, around 2150 hectares, whilst the area of pavement unaffected by stone removal and displacement is estimated at 813 hectares (about 40%).

Case Study 2: Scar Close - Limestone Pavement

- *Scar Close is a relatively small (97 hectares) part of the larger Ingleborough. It is located in the western part of the Yorkshire Dales National Park.*
- *The surface characteristics of the rock, namely the depth and shape of the fissures of the pavement, influence light and moisture availability, humidity and windspeed as well as offering protection from grazing. In the deeper grikes there is greater floristic diversity due to the modification of the biotic and abiotic characteristics.*
- *Scar Close shows an interesting assemblage of geological features. The geology is exceptionally massive and includes deep grikes and large pyramidal and tabular clints. Parts of the reserve are grazed by sheep, but the pavement itself is infrequently grazed due to restricted access, although smaller herbivores, e.g. rabbits cannot be controlled.*
- *Fig. 8 shows a topographic map for a selection of grikes, and the distribution of plants. Notable plants at Scar Close include the Rigid Buckler Fern (exclusively confined to pavement habitats) and Baneberry. A significant proportion of Britain's population of this plant is found at Scar Close.*

Fig. 8 Scar Close topographic map.



Many are located within National Parks, whilst others are specially protected with SSSI (Site of Special Scientific Interest) status, or within NNRs (National Nature Reserves). Yet pavement quality is being reduced by increased grazing pressure and by damage done by tourism activity. More significantly, some pavements are being broken up, removed, and sold off to be used as garden rockeries and water features. Under Section 34 of the Wildlife and Countryside Act 1981, local authorities may make a limestone pavement order (LPO) which makes it an offence to remove limestone from an area of land. This protection was introduced in response to the widespread destruction of limestone pavement features for sale as rockery stone.

The future for karst landscapes

Karst limestone areas are a valuable part of our natural heritage, but they are also under threat from several sources:

- *agricultural intensification*
- *water pollution*
- *dumping*
- *insensitive tourism /development*
- *destruction for use in gardens*
- *vandalism*
- *bad caving practice*
- *quarrying*

Why should the best examples of these features be conserved?

- They are an integral part of our natural heritage
- We have a duty to future generations to preserve our heritage so that it may become theirs.
- Karst has a distinctive character. To the usual three-dimensional relief, karst landforms add a 'fourth dimension', namely the subterranean relief, a sort of negative replica of the surface drainage patterns, to which it is closely connected.
- Limestone areas support unique and diverse floral assemblages, together with the associated fauna.

What are the benefits of preservation?

- Karst areas have a distinctive beauty for both local people and visitors (environmental value)
- The tourism potential of areas like the Burren (Ireland) and Malhamdale (economic value)
- They are a valuable scientific and educational resource
- They are fundamental in understanding and appreciating our historical, ecological and archeological heritage
- They are often the only source of drinking water, particularly in rural areas (spring-line villages)

What should be conserved?

The objective must be to conserve the best examples of the main karst features. 'Best' can be considered at international, national and county levels. The main features include caves, limestone pavement, sinking streams, karst springs and massive karst landscapes.

Achieving successful conservation involves: selecting sites worthy of conservation; identifying practical site management techniques; having a good legislative framework backed up by site monitoring; and increasing public awareness and support. Conservation has to be embraced by the landowners who are custodians of these special areas for everybody, and the public must in turn support them and their efforts. Therefore, it is essential to see local people as partners or stakeholders in karst conservation.

Further research

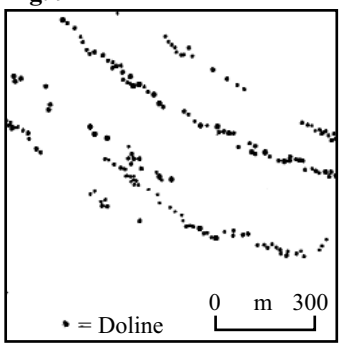
Clayton, K (1981) Explanatory Description of the Landforms in the Malham Area, Field Studies 5, p389-423 (off-print). Field Studies Council, Shrewsbury.
Jennings, J (1985) Karst Geomorphology. Blackwell.
Selby, M.J (1985) Earth's Changing Surface. Oxford. *Contains chapter on Karst landforms.*

Useful websites

www.bgs.ac.uk/education/britstrat/home.html Easy to use geological time-chart
www.gsi.ie/workgsi/groundwater/karstbook/karst-fra.htm High quality site about limestone in Ireland. Details about the Marble Arch Cave system.
www.limestone-pavements.org.uk/ Limestone Pavement Action Group.

Exam Questions

Fig. 9



1) a) *Fig. 9* shows the pattern of dolines found in a surveyed area near Malham, North Yorkshire. Describe and account for the distribution of these surface limestone features. *(4 marks)*

b) Using the information in *Fig. 3* and your own knowledge, describe the development and evolution of two named surface limestone features. *(10 marks)*

c) With reference to a named area of karst scenery within the UK or Ireland, produce a 'for' and 'against' table which examines the environmental and socio-economic implications for large-scale limestone extraction. *(10 marks)*

2. Design a programme of fieldwork to assess impact of a new limestone cave system which has been recently opened as a tourist attraction. *(20 marks)*

Answer Guidelines

1) a) The pattern of dolines is mostly high density, and they tend to occur in linear lines, running in a NW to SE direction / orientation. In the SW section of the survey area there are no dolines. This would suggest a change in geology, i.e. from limestone to an impermeable rock.

b) A number of features can be identified, e.g. dry valleys, sinks, resurgences etc. Make reference to their position on *Fig. 3*. Top marks will be awarded for full explanation of evolution, related to geology.

c)

	For	Against
Environmental	Clean up operation is integral to any new development. Regeneration may provide for the creation of new habitats/ecosystems Road traffic problems could be minimised with increased use of rail. Limestone can be used in coal-fired power stations as a flue-gas desulphuriser: reducing gas emissions	Many ecological arguments associated with loss of habitats, especially prime sites Visual impacts of factory – loss of landscape amenity Noise pollution both from the factory works & associated increased traffic. Increased heavy vehicle traffic will cause road congestion & dust pollution.
Socio-economic	Improvements in local infrastructure Local employment opportunities: range of skilled & semi-skilled labour More money being spent in local economy, e.g. retailing May attract other associated (processing) industries	May encourage less tourism to the area, causing decreased activity for hotels, B&Bs Some local/traditional industries may be forced to leave the area because of problems with road traffic etc. Larger company may suck local employment out of the area, leaving other industries without a suitably skilled labour pool

2) To monitor impact, then base line survey data is needed, i.e. what the area was like prior to the new attraction. This will probably be based on a comparison survey in a similar habitat / area (geographically close). Some ideas might include:

- Ecological surveys of plant diversity, birds populations etc
- Traffic and visitor surveys (including sphere of influence).
- Could also use a decibel meter to assess noise.

For the area which now hosts the attraction:

- Repeat above surveys (using identical sampling strategy)
- Carry out interviews with local shop keepers, residents and other interested parties. Assess rationale for their views.
- Develop an impact matrix for activities

Assess likely sources of secondary data – could also use cost-benefit analysis. For top marks you need to put forward a range of sensible ideas. The answer also needs to be well structured and demonstrate depth.

Acknowledgements *This Factsheet was researched by David Holmes who is geography adviser to the Field Studies Council and works part-time at King Edward VI College in the West Midlands.* **Curriculum Press.** Unit 305B, The Big Peg, 120 Vyse Street, Birmingham B18 6NF. **ISSN 1351-5136**