



Geography





ORGANISATIONAL DETAILS

Aim

River features and processes of the upper course.

Target Group

Key Stage 3 and 4 geography

Location

This fieldwork day starts at Bowlees, to the west of the hamlet of Newbiggin in Upper Teesdale. Three river sites are identified for the river measurements to be carried out. These are a tributary to Bow Lee Beck (GR: NY 909285), a site on Bow Lee Beck above the tributary (GR: NY 909 285) and a site below the tributary (GR: NY 907284). During very low flow conditions a fourth site above Gibsons Cave and Summerhill Force could be used if the tributary to Bow Lee Beck is dry (GR: NY 909293). The second part of the fieldwork involves visiting High Force (GR: NY 881284). You may want to walk to High Force along the route shown on the O.S. map or use your transport to move between Bowlees Nature Reserve and the car park at High Force.

Practical Details

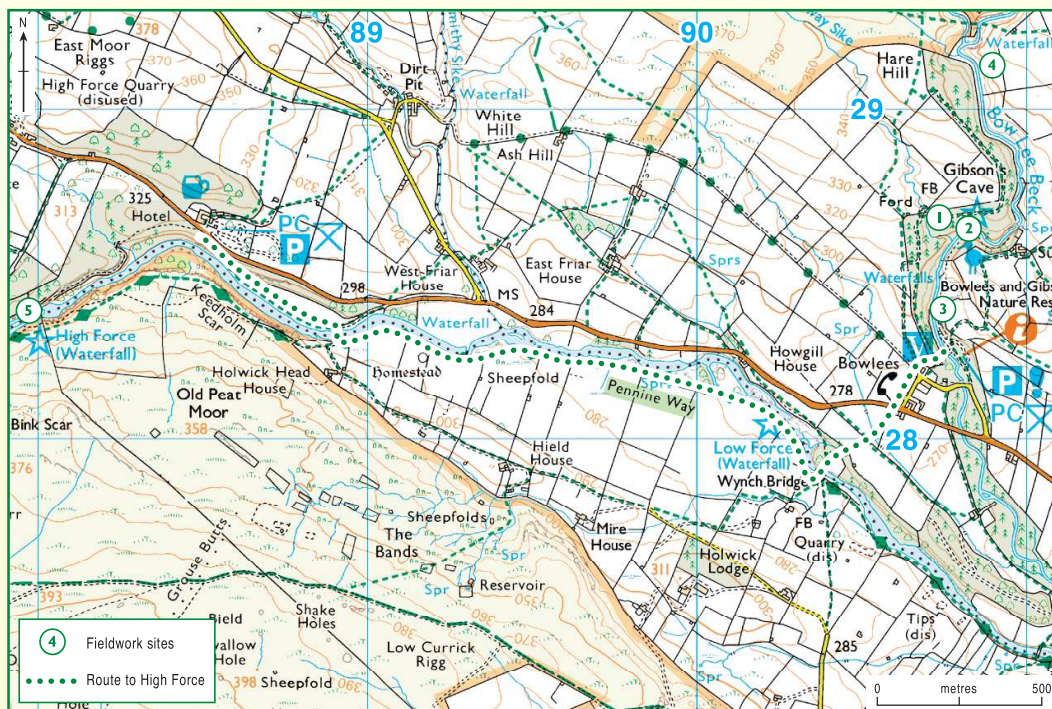
- Parking – There is free parking at Bowlees Nature Reserve. Parking for coaches is on the main road (GR: NY 905281). The three river sites and Gibson's Cave are within easy walking distance. If it were necessary to use the fourth river site above Summerhill Force, access would be via the hamlet of Newbiggin. There is a charge for the car park at High Force.
- Charges – There are no charges at Bowlees Nature Reserve but there is an entrance charge for the waterfall at High Force.
- Toilet facilities – There are toilets at Bowlees Nature Reserve and at High Force
- Picnic areas – There are picnic areas at both Bowlees Nature Reserve and High Force.
- Useful map – Ordnance Survey 1:25 000 Explorer OL31 North Pennines Teesdale and Weardale

Safety Issues

- The fieldwork activities at Bowlees Nature Reserve will involve the students working in the river and the fieldwork should only be undertaken at low flow conditions.
- Refer to the Hazard Identification Sheet

River Features and Processes in Upper Teesdale

Fieldwork Outline - Teacher Resource Sheet



HAZARDS IDENTIFICATION SHEET

The following notes will help teachers conduct their own risk assessments. This is not a risk assessment and teachers should follow guidelines from the Department of Children, Schools and Families.

Hazard Identified	Risk and to whom	Control measures
Vehicles in the car park	Caution needed when getting off the coach or minibus in the car park as the parking area is narrow and vehicles may be passing. All students and staff.	Supervise students getting off the coach or minibus and gather in a safe place.
Vehicles on the road	Students need to get off the coach at the lay-by on the main road. Cars travel fast along this stretch of road. All students and staff.	Supervise students along the road.
Uneven paths	Paths are uneven and may be slippery in wet weather. Students may slip and fall. All students and staff.	Warn about conditions.
Working in rivers	Rocks in the river may be slippery and there is the risk of falling into the river. All students and staff.	Warn about conditions and the possibility of hypothermia if getting wet.
Walk to High Force	River bank unfenced. Steep unfenced drop on last section of path before reaching High Force Hotel. All students and staff.	Warn about river. One person on the Wynch Bridge at a time. Keep together as a group.
High Force car park	Traffic in car park. All students and staff.	Supervise students getting off the bus.
High Force	Traffic present when crossing the road. Path to High Force may be slippery and uneven. Falling into a fast flowing river. All students and staff.	Supervise students crossing the road. Warn of conditions. No one allowed beyond the wall at the viewing point to the waterfall.

INTRODUCING THE FIELDWORK

Purpose and aims of the visit:

The main purpose of the fieldwork is to look at the features and processes that operate in the upper course of a river.

The aims of the fieldwork are:

- To look at the features of the upper course of Bow Lee Beck
- To look at the features of waterfall formation at Gibson's Cave and High Force
- To find out what controls the energy levels of the river.
- To find out how changes in energy affect the processes at work in the river.

Background information

The features of a river vary from source to mouth. The energy available for erosion, transportation and deposition vary with time and over the course of the river. Introduce river features and processes using Student Information Sheet 1.

Having introduced the aims of the fieldwork, set up hypotheses based upon the following:

- What factors influence how fast a river flows?
 - Gradient?
 - Amount of water in the river? (Discharge)
 - Shape and efficiency of the channel? (Cross sectional area, hydraulic radius)
- Where will the river have most energy?
- Where does the river flow fastest?
- What processes will be dominant in different parts of the river?
- How does the material carried by the river change with the river's course?
 - Size?
 - Shape?

Introducing fieldwork methods

Introduce the fieldwork methods needed to test the hypotheses. Use Student Information Sheet 2 to introduce the methods.

Use the O.S. extract to show the location of the river sites.

UNDERTAKING THE FIELDWORK

1. Bowlees Nature Reserve – river measurements

River measurements are to be carried out on 3 sites. The first is a tributary to Bow Lee Beck, the second is on Bow Lee Beck but above the point where the tributary enters the beck and the third is below where the tributary enters the beck. See O.S. map extract.

At each site the following measurements are carried out:

- Width
- 10 x depth recordings
- Wetted perimeter
- Float velocity – 10 x across the river
- Flow meter velocity – 10 x across the river
- Gradient
- Bedload test
- Suspended load test
- Measurement of the A-axis of 10 pebbles
- Measurement of the roundness of 10 pebbles
- Field sketch and description of the river features. The main features to observe are the 'v'-shaped valley, interlocking spurs, pools and riffles and waterfalls.

All measurements can be recorded on Student Resource Sheet 1.

2. Bowlees Nature Reserve – Gibson's Cave and Summerhill Force

At Gibson's Cave a closer look at waterfall formation can be made. In this case the more resistant capping rock of the waterfall is limestone and the softer underlying rocks are layers of sandstone and shale. A field sketch of the waterfall can be made and the layers of rock labelled. Relate the formation of the waterfall to Student Information Sheet 1.

3. High Force

A visit to England's highest waterfall will reinforce the process of waterfall formation. Using the information boards work out the more resistant and less resistant rocks involved in forming this waterfall. (Resistant rock is dolerite – whinstone – and the less resistant rocks are sandstone and limestone). Make a field sketch of High Force and label the rock types.

Fieldwork equipment

The following equipment will be required:

Clipboards
30m tapes
Metre rules
Float – boneo (biodegrades if left behind or eaten by sheep!) or orange
Stopwatch
Flow meter
Gun clinometer
Laminated board and spring balance
Pot for suspended sediment
Student Resource Sheet 1 – Recording Sheet.

FOLLOWING UP THE FIELDWORK

Presenting and describing your results

1. Processing the data

Use Student Resource Sheet 2 to process the data collected in the field. Each group should use their own data. This will allow the students to see the change in the river's characteristics as they move from site 1 to 3 (i.e. as they move downstream).

2. Cross sectional areas

Using graph paper plot the cross sectional areas of the 3 river sites. Use these to describe the shape of the river channel. The shape can be related to the amount of water in touch with the bed and banks of the river and so the amount of friction produced. The channel shape with the least amount of water in contact with the bed and banks will be more efficient. Relate these cross sectional areas to the results for the hydraulic radius, which is a measure of the efficiency of the river.

3. Field sketches

Tidy the field sketches made and add the site description information to them.

4. Describing your results

For each of your results describe what they show.

5. Analysing your results

Use the data collected to accept or reject the hypotheses set up before the fieldwork. Explain what your results mean.

6. Summarising your results

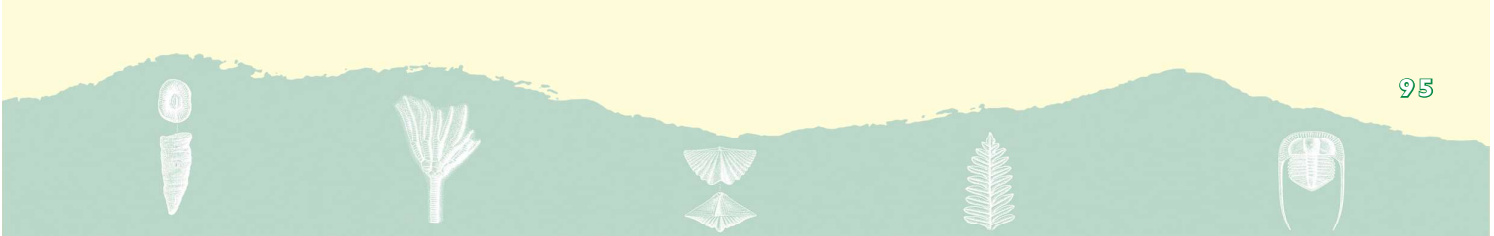
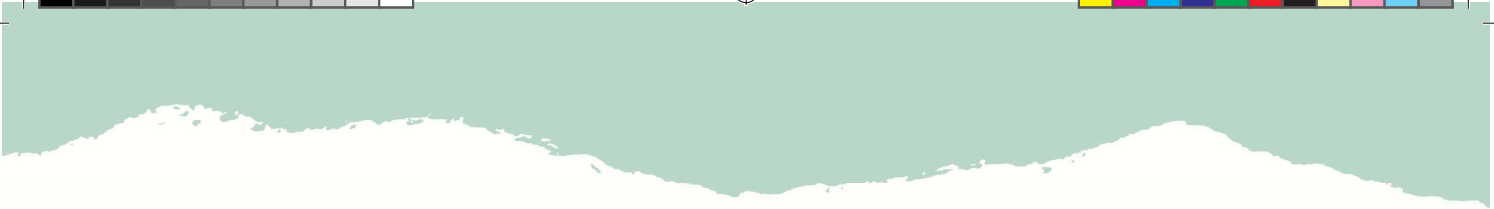
From the results summarise the following:

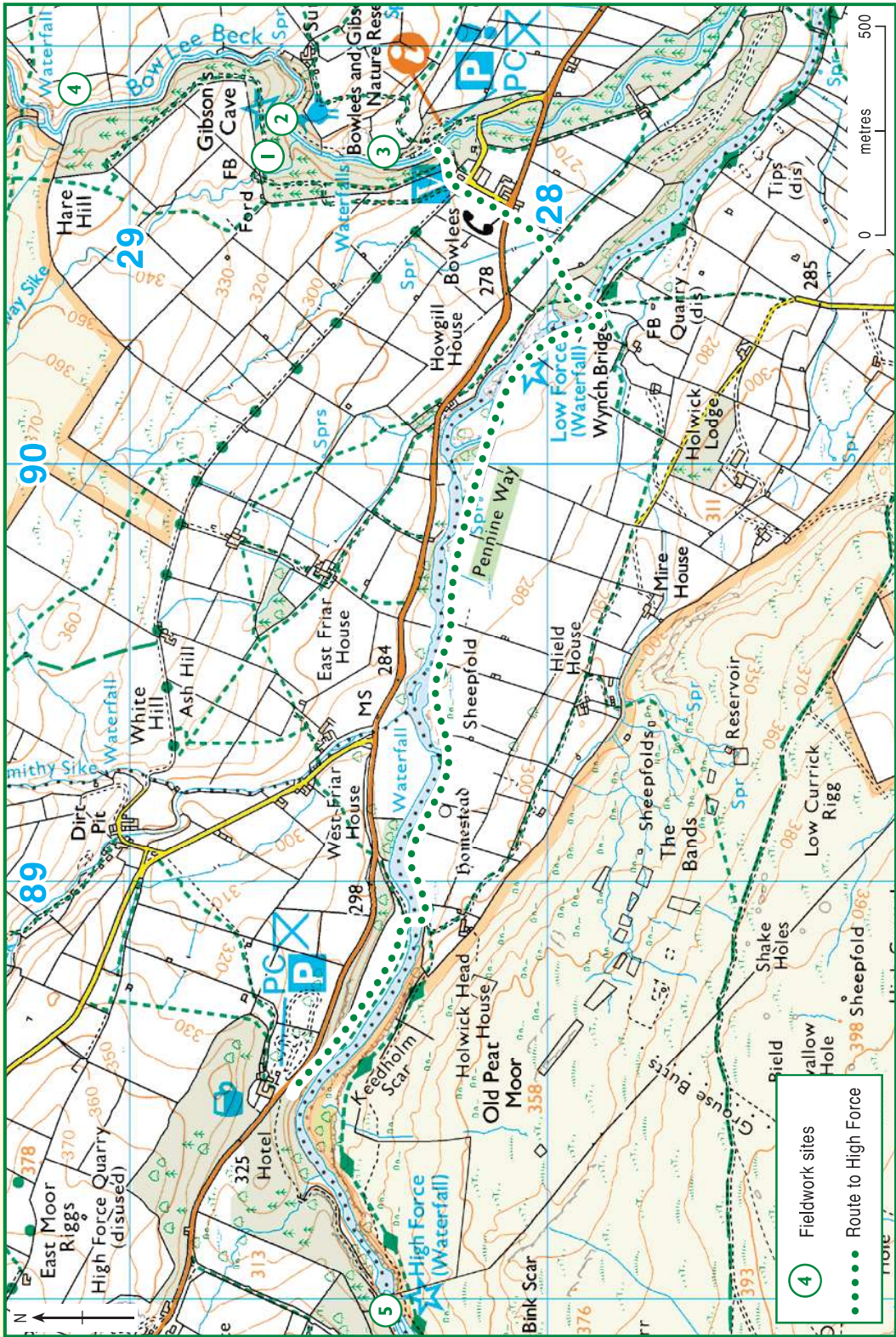
- What are the controls on velocity and what are the relationships?
- Where does the river flow fastest and why?
- Where does the river have the most energy?

- What processes are most important at each site?
- How is this outcome reflected in the shape and size of the pebbles you measured?

Additional work

- Use a range of graphical techniques to present the results.
- Use Spearman's Rank Correlation Coefficient on the results to identify significant positive and negative correlations between the variables measured in the field.
- Use the measurements to calculate Manning's 'n' – a measure of the channel's roughness.
- Use the case study of the River Gaunless Flood Alleviation Scheme to look at the factors that affect flooding on a North Pennines river and a flood alleviation scheme that has been put in place.





O.S. map of the fieldwork sites and route to High Force

Ordnance Survey Map Symbols

ROADS AND PATHS

	Motorway
	Dual carriageway
	Main road
	Secondary road
	Narrow road with passing places
	Road under construction
	Road generally more than 4m wide
	Road generally less than 4m wide
	Other road, drive or track, fenced and unfenced
	Path

RAILWAYS

	Multiple track
	Single track

PUBLIC RIGHTS OF WAY

	Footpath
	Bridleway

BOUNDARIES

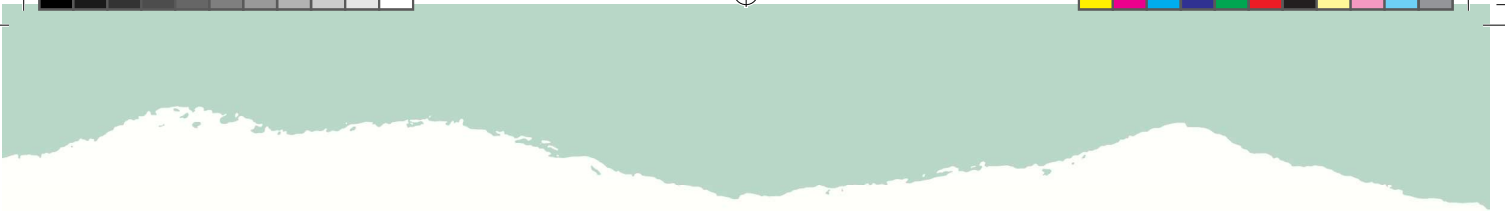
	National
	County (England)
	Civil Parish (CP)
	National Park boundary

SELECTED TOURIST AND LEISURE INFORMATION

	Parking
	Information centre
	Public convenience
	Telephone
	Campsite / caravan site
	Golf course or links
	Public house
	Walks
	Viewpoint
	Picnic site
	Country park

GENERAL FEATURES

	Place of worship
	Building
	Bus or coach station
	Triangulation pillar
	Windmill
	Boundary post / stone
	Clubhouse
	Footbridge
	Monument
	Post Office
	Police station
	School
	Town hall



River Features and Processes in Upper Teesdale

Student Information Sheet 1

RIVER FEATURES

Rivers usually start on high land and flow to the sea. The start of a river is called the **source** and where it enters the sea is called the **mouth**.

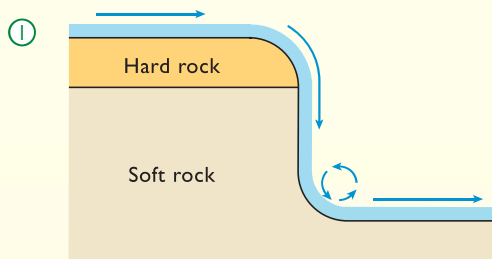
The main features of the upper course are features produced by erosion and include 'V' shaped valleys, interlocking spurs, waterfalls and rapids:

'V' shaped valleys – the energy of a river in its upper course is used to cut downwards, developing steep-sided, narrow valleys shaped like the letter 'V'.

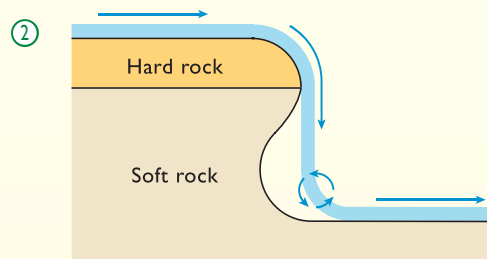
Interlocking spurs – the river is forced to wind its way around protruding hills and outcrops of rock. The protruding outcrops are called interlocking spurs and restrict the view up and down the valley.

Waterfalls – most waterfalls are formed when the river meets a band of softer, less resistant rock after flowing over a relatively hard resistant rock. The softer rock is worn away more quickly and the harder rock is undercut. The undercut rock will be unsupported and will eventually collapse. The rocks that have collapsed, will be swirled around by the river at the foot of the waterfall and create a plunge pool. This process will be repeated and the waterfall will move upstream leaving a steep-sided gorge in front of it.

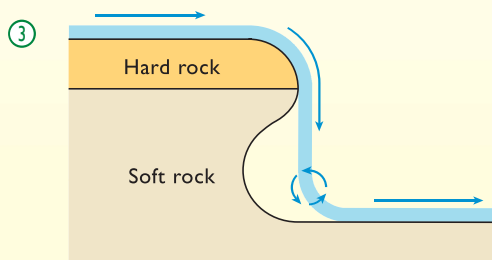
How are waterfalls formed?



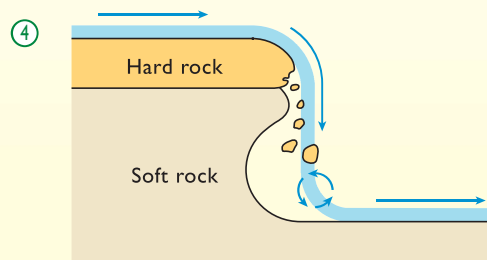
STEP 1: Most waterfalls are formed when the river meets a band of softer, less resistant rock after flowing over a harder, more resistant rock.



STEP 2: The softer rock is worn away more quickly to form a step in the bed of the river.



STEP 3: The harder rock is undercut by the river.



STEP 4: The undercut rock is left unsupported and will collapse.

Rapids – these occur where the layers of hard and soft rock are narrow and so there is no break in slope like when a waterfall is formed. The wearing away of the less resistant rock makes the gradient steeper producing rapids or areas of fast flowing water. There are often sequences of fast and slow flowing water called pools and riffles.

The main features of the lower course are depositional and include, **flood plains, levees** and **deltas**. **Meanders** and **ox-bow** lakes are the result of both erosion and deposition. These features will not be seen, as our study will be concentrated on the upper course.

RIVER PROCESSES

The river has three types of processes: erosion, transportation and deposition.

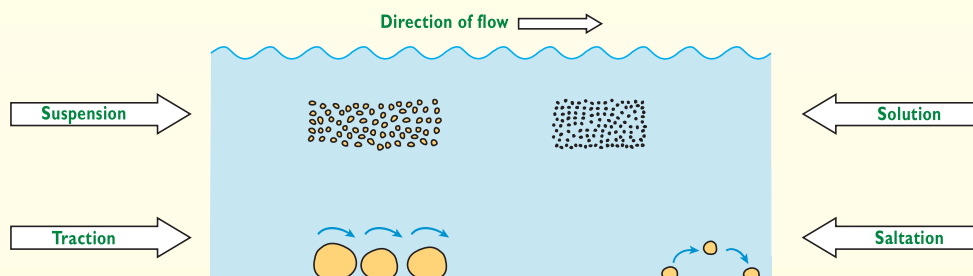
Erosion – The material carried by a river erodes the bed and banks. A river erodes by 4 different processes:

- **Attrition** – boulders and material moved by the river along its bed, collide and break up into smaller pieces. This is the main process of erosion in the river's upper course.
- **Corrasion** or **Abrasion** – material carried by the river in suspension (carried in the water) wears away the banks of the river. This is the main process of erosion in the lower course, as the material carried by the river is small enough to be transported in suspension.
- **Corrosion** – this where slightly acidic river water dissolves the bedrock when it is an alkali rock like limestone. This can occur at any point during the river's course.
- **Hydraulic action** – this where the force of the water in the river dislodges particles from the river's bed and banks.

Transportation – The river can transport material by 4 main processes: traction and saltation along its bed, suspension and solution within the river itself.

- **Traction** – this is the rolling of stones along the bed of the river and requires the most energy.
- **Saltation** – sand-sized particles bounce along the riverbed.
- **Suspension** – silt and clay-sized particles are carried within the water itself
- **Solution** – this is where minerals are dissolved in the water and are carried along. This method of transport requires the least energy.

Transportation in a river



Deposition – this occurs when the river does not have enough energy to carry its load and the material is dropped onto the bed or banks of the river. The heaviest material is dropped or deposited first and may occur when the amount of water (or discharge) in the river is reduced or the velocity of the water decreases such as on the inside of a meander bend.

The river's energy

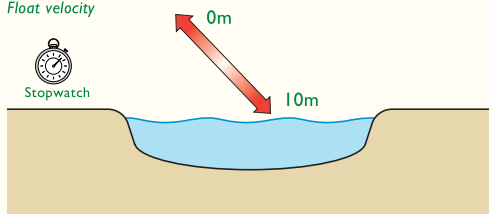
Energy levels in a river vary over time and over the course of a river. When energy levels are high the river can transport material and erode the bed and banks. If energy levels fall the river may not be able to transport, as much material and it will be deposited.

River Features and Processes in Upper Teesdale

Student Information Sheet 2

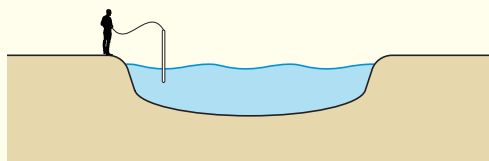
1. Velocity measurements

Float velocity



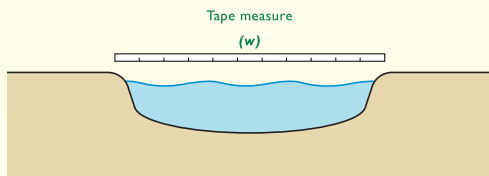
Record the time it takes for the float to travel 10m. Repeat the exercise 10 times across the width of the river.

Flow meter velocity



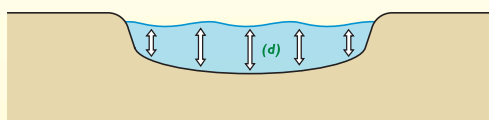
Place the flow meter in the river 2/3 up from the bottom or 1/3 down from the top. Record the velocity 10 times across the stream.

2. Width



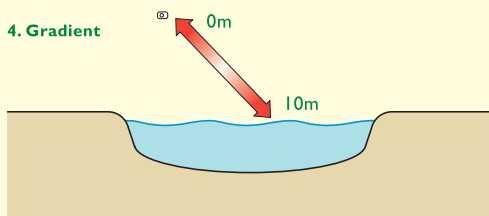
Measure the width of the stream from the surface of the water on one side to the surface of the water on the other side.

3. Depth (m)



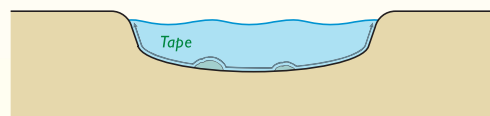
Take 10 depth measurements across the width of the river.

4. Gradient



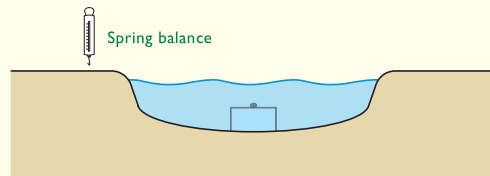
Use the gun clinometer over 10m. Site on the eyes of a person the same height as yourself and when the gun clinometer stops swinging, stop it and read the angle.

5. Wetted perimeter



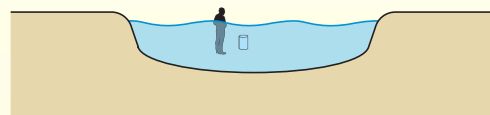
Measure the wetted perimeter from the surface of the water on one side, over every hump and bump on the river bed, to the surface of the water on the other side.

6. Bedload test



Weigh the pebble that gradually moves across the laminated board on the bed of the river.

7. Suspended load



Collect a sample of water from the middle of the river.

8. Size and shape of bedload

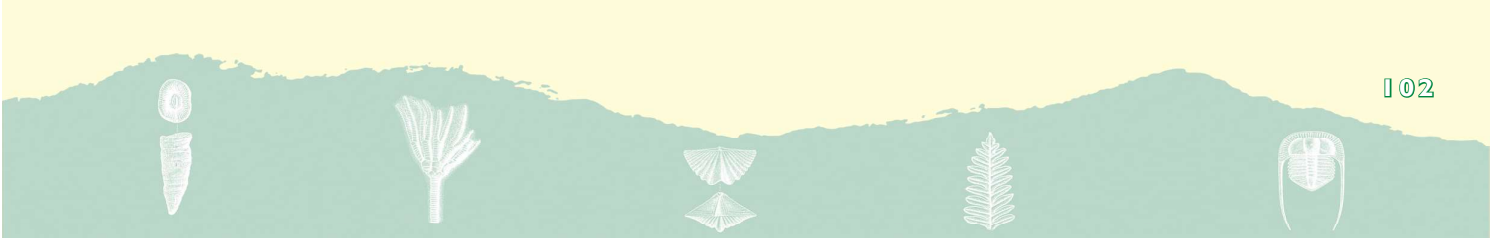
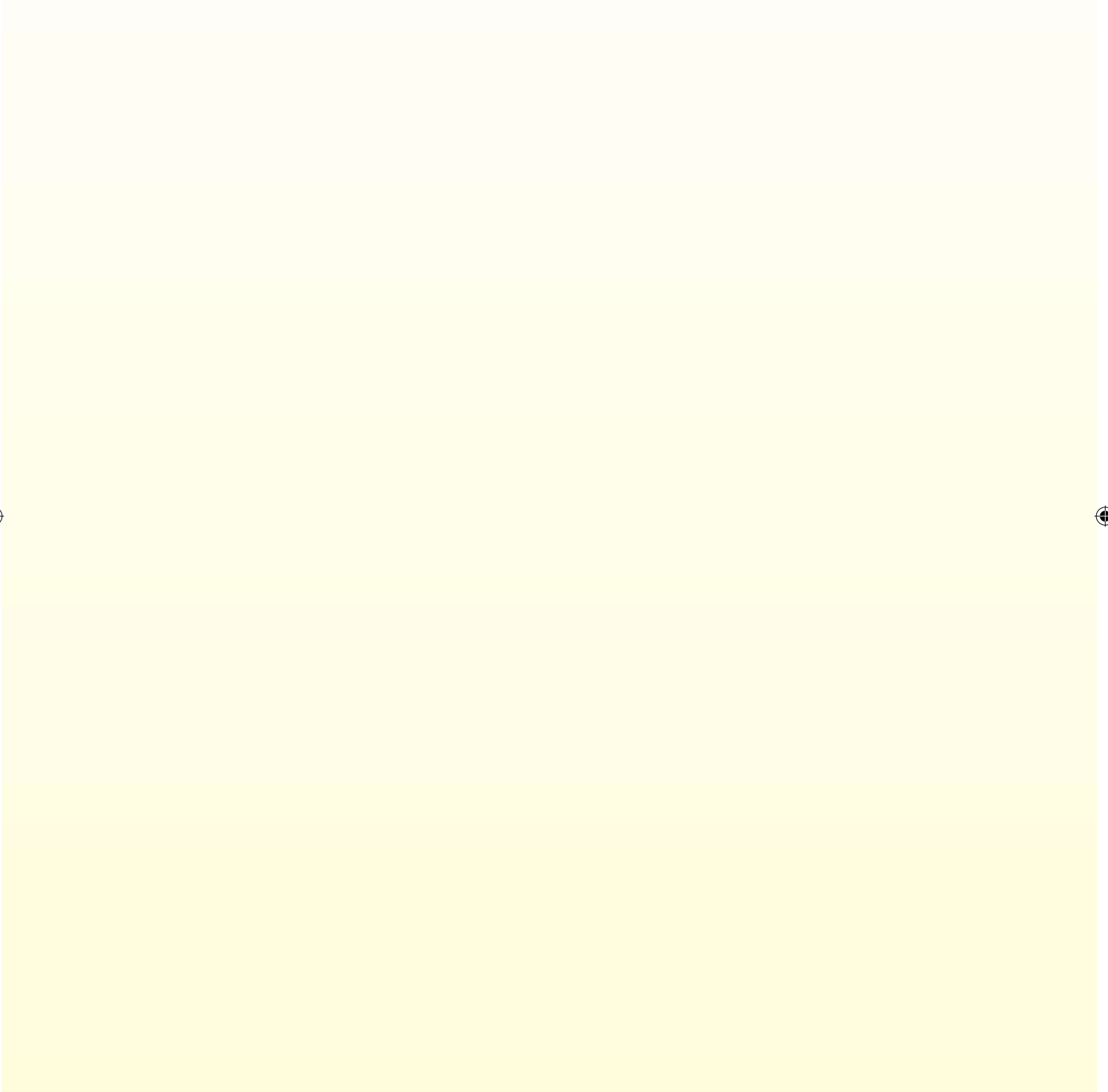
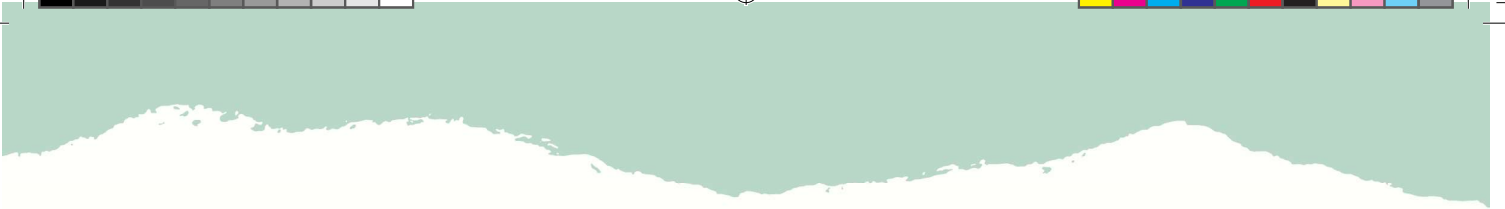


Record the length of the A-axis of 10 pebbles

Record the roundness of 10 pebbles using the roundness chart

9. Site description

Fill in description on the recording sheet. Describe the features of the upper course. Draw a field sketch or take a photograph and label the main features.



River Features and Processes in Upper Teesdale

Student Resource Sheet 1

RIVER RECORDING SHEET

Results	Site 1 Name:	Site 2 Name:	Site 3 Name:	Site 4 Name:
Grid reference				
Width (m)				
Depth (cm)				
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
Wetted perimeter (m)				
Float velocity (time taken to travel 10m)				
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				



Results	Site 1 Name:	Site 2 Name:	Site 3 Name:	Site 4 Name:
Float metre velocity (m/s)				
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
Gradient (degrees)				
Mass of pebble that just moves across board (g)				
Depth of sediment from suspended load (mm)				
Length of A-axis (cm)				
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				



Results	Site 1 <i>Name:</i>	Site 2 <i>Name:</i>	Site 3 <i>Name:</i>	Site 4 <i>Name:</i>
Bed load shape:				
No. Angular				
No. Sub-angular				
No. Sub-rounded				
No. Rounded				
Site description:				
1. Size of valley				
2. Steepness of valley				
3. Is the river large or small compared to the valley				



Field Sketches

Site 1: _____

Site 1: _____

Site 1: _____

Site 1: _____

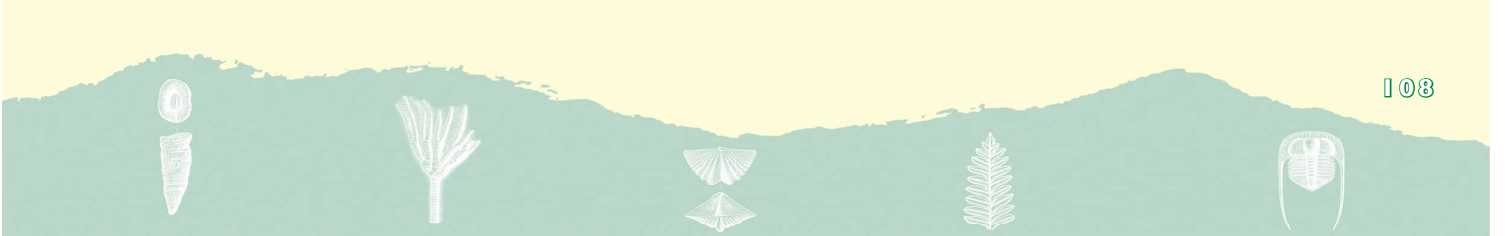
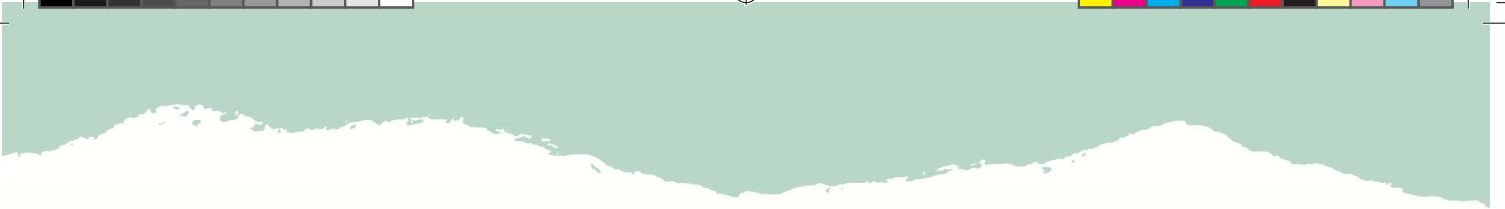


River Features and Processes in Upper Teesdale

Student Resource Sheet 2

RIVER ANALYSIS SHEET

	Site 1 Name:	Site 2 Name:	Site 3 Name:	Site 4 Name:
Width (m)				
Mean depth (m) (add 10 depth measurements together and divide by 10)				
Cross sectional area (CSA) (m²) (Width x mean depth)				
Mean float velocity (m/s) (10 divided by the mean number of seconds)				
Mean flow meter velocity (m/s)				
Discharge (m³/s) (CSA x flow meter velocity)				
Wetted perimeter (m)				
Hydraulic radius - a measure of the efficiency of the stream (CSA divided by wetted perimeter)				
Gradient (degrees)				
Mass of pebble (g)				
Bed load shape				
% Angular				
% Sub-angular				
% Sub-rounded				
% Rounded				
Bed load size (mean length of A-axis (mm))				
Depth of suspended sediment (mm)				





ORGANISATIONAL DETAILS

Aim

To look at features of limestone scenery and sustainable development at East Mellwaters Farm.

Target Group

Key Stage 4 geography

Location

This fieldwork day is based at East Mellwaters Farm with an option of going to Slapestone Bridge, North Stainmore. Both sites are located along the A66 in Teesdale in Co. Durham.

The whole day can be spent at East Mellwaters Farm (GR: NY 968125). The first half of the day will involve a circular walk around the farm looking at the importance of the geology and geomorphology of the area. The second half of the day will look at what the farm is doing to promote sustainable development.

Alternatively the second half of the day could continue to look at limestone features with a visit to the limestone pavement at Slapestone Bridge, North Stainmore (GR: NY855146). This session will involve a piece of enquiry-based work on the limestone pavement.

Practical Details

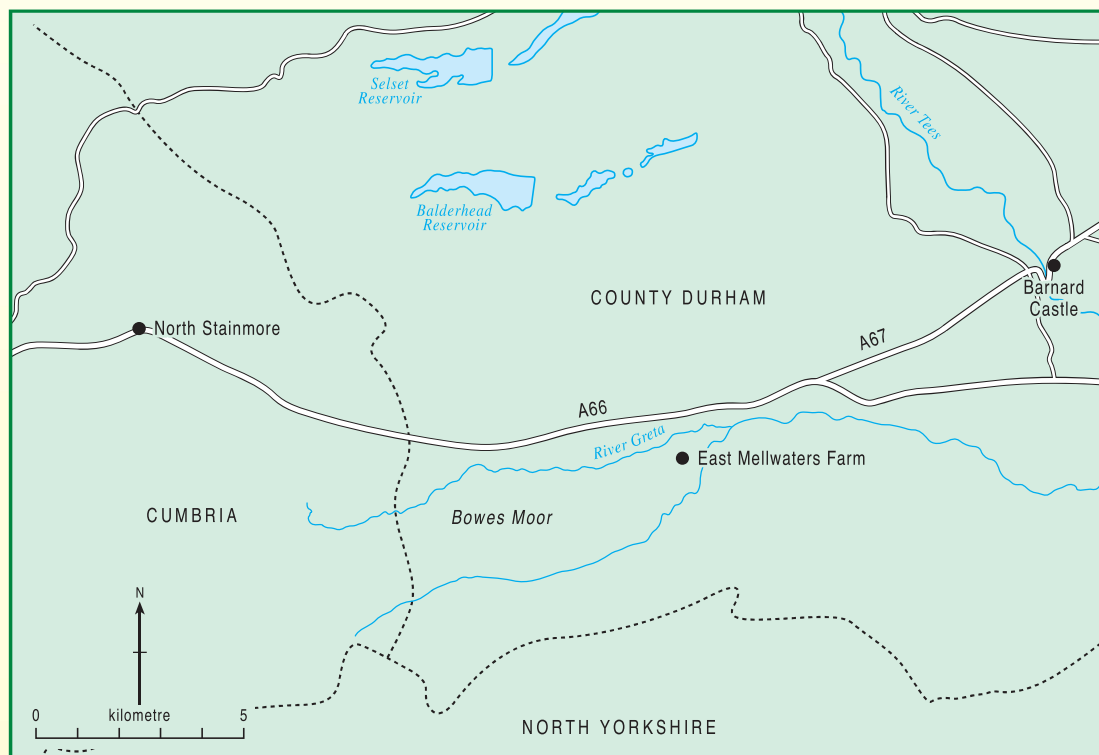
- Parking – East Mellwaters Farm is not accessible by coach but the coach can pull in at the entrance to the farm (GR: NY 969132). The day involves a circular walk and the group can be picked up at God's Bridge lay-by (GR: NY 956127). Minibuses may park in the farm or can drop pupils off and then park in the lay-by above God's Bridge. There is ample parking space at North Stainmore just off the A66.
- Useful maps – Ordnance Survey 1:25 000 Explorer OL31 North Pennines Teesdale and Weardale and Ordnance Survey 1:25 000 Explorer OL19 Howgill Fells and Upper Eden Valley.

Safety Issues

- Bowes Moor is high on the North Pennines and is exposed (East Mellwaters Farm 300m a.s.l. and Slapestone Bridge 370m a.s.l.). Staff and students should be prepared for extreme weather conditions.
- The A66 is a very busy road and students should be supervised on and off the coach.
- Refer to the Hazard Identification Sheet.

Limestone Landscapes on Bowes Moor and Sustainable Development

Fieldwork Outline - Teacher Resource Sheet



HAZARDS IDENTIFICATION SHEET

The following notes will help teachers conduct their own risk assessments. This is not a risk assessment and teachers should follow guidelines from the Department of Children, Schools and Families.

Hazard Identified	Risk and to whom	Control measures
Getting on and off the coach or minibus	Caution needed when getting off the coach or minibus as both the dropping off point and the collection point are at lay-bys on the A66. All students and staff.	Supervise students getting off the coach or minibus and gather in a safe place.
Weather	Bowes Moor is high and exposed. There is the risk of hyperthermia in cold conditions and exposure to the sun in the summer. All students and staff.	Warn about conditions. Wear suitable clothing and footwear for the weather conditions.
River levels	The Greta and Sleightholme rivers can rise very quickly and may rise from low flow to above bank full conditions within 2 hours. The River Greta may flow over the top of God's Bridge in very wet conditions. All students and staff.	Warn about conditions.
Uneven paths	Paths are uneven and may be slippery in wet weather. Students may slip and fall. All students and staff.	Warn about conditions and the possibility of hypothermia if getting wet.
Unfenced sections of river	The river is unfenced in certain sections - God's Bridge on the River Greta and below The Trough on the Sleightholme Beck. All students and staff.	Warn about conditions. Close supervision needed along the unfenced river sections.
Farm traffic	East Mellwaters is a working farm and there will be farm traffic, especially near the farm buildings. All students and staff.	Warn about farm traffic and provide close supervision whilst near to the farm buildings.
Uneven and slippery rocks at Slapestone Bridge, North Stainmore	The limestone pavement at Slapestone Bridge is slippery especially in wet conditions and is very uneven. All students and staff.	Warn about condition and wear sensible footwear

INTRODUCING THE FIELDWORK

Purpose and aims of the visit

The main purpose of the fieldwork is to look at the processes and features of limestone landscapes and in the case of East Mellwaters Farm to look at the how the farm is contributing to sustainable development.

The aims of the fieldwork are:

- To investigate the geology of East Mellwaters Farm
- To look at the limestone features of the area
- To record the work undertaken by East Mellwaters Farm that is contributing to sustainable development, or
- To carry out an enquiry on the limestone pavement at Slapestone Bridge, North Stainmore.

Background information

An introduction to the features of limestone scenery can be given prior to the visit using Student Information Sheet 1. The sustainable development or limestone pavement enquiry can be introduced in the field.

Introducing fieldwork methods

1. Limestone scenery at East Mellwaters Farm - The fieldwork for this element of the day is based on a walk around the farm and the surrounding area. Information for each site is provided in the 'Undertaking fieldwork' section and information can be recorded by the students on Student Resource Sheet 1.

2. Sustainable development at East Mellwaters Farm – A base map of the farm is provided in Student Resource Sheet 2 which identifies points where improvements have been made to the farm that benefit the environment and wildlife, provide for recreation, leisure or educational activities or provide an economic future for the farm. Using the key provided the students identify and mark on the map the improvements that have been made at each location. This work can be conducted in small groups or as a class. Introduce the work from the Pack Horse Bridge. It will be necessary to walk the circuit from the farm to Caldwell Bridge to the river cliff and back again, to look at the area around the farm buildings and then the rest of the features can be seen on the walk back to God's Bridge to meet the coach or minibus. Additional information about Mellwaters Barn is available from the farm's website and could be looked at in advance (www.mellwatersbarn.co.uk). A conservation walks leaflet is available by visiting the Defra website and searching on conservation walks (www.defra.gov.uk).

3. An enquiry into the limestone pavement at Slapestone Bridge, North Stainmore – The purpose of this fieldwork activity is to provide a closer look at a limestone pavement and to carry out a small enquiry that illustrates all the planning required for such an exercise. Introduce the work using Student Information Sheet 2 and record the work on Student Resource Sheet 3.

UNDERTAKING THE FIELDWORK

1. Limestone scenery at East Mellwaters Farm

The table below provides information about each stop on the walk and students can record the information on Student Resource Sheet 1.

2. Sustainable development at East Mellwaters Farm

This fieldwork records the improvements made at East Mellwaters Farm and can be completed as a class or in small groups. Introduce sustainable development using Student Resource Sheet 2 and then using the key, record the improvements on the base map. The key can be used to discuss the things to look for in advance. Information from the farm's website about Mellwaters Barn can be provided or made reference to as can the conservation walks from Defra's website.

3. An enquiry into the limestone pavement at Slapestone Bridge, North Stainmore

Access to the limestone pavement is gained through a gate on the right hand side of the track that runs along Smeltmill Beck (GR: NY 852148). Use Student Information Sheet 1 to look at the main features of a limestone pavement. Use Student Information Sheet 2 to introduce the enquiry. The results can be recorded on Student Resource Sheet 3.





Location and grid reference	Background information
1. Pack Horse Bridge (GR: NY 967128)	<p>East Mellwaters is a working upland sheep farm of 110 hectares. The farm is all permanent pasture, with the land surrounding the farm buildings. The farm has 400 sheep (with a further 600 lambs after lambing) and 35 suckler cows (with a further 65 after calving). Farming is carried out in an environmentally sympathetic way at East Mellwaters – no artificial fertilisers are used, there is no blanket spraying of herbicides and the land is not overstocked.</p> <p>The farm is located in the North Pennines Area of Outstanding Natural Beauty and European Geopark in Co. Durham. It is 1.5 miles west of Bowes village on the main trans-Pennine A66 trunk road. The farm has many geological, geomorphological, ecological and historical features of interest. Complete activity 1 on Student Resource Sheet 1.</p>
2. Cardwell Bridge (GR: NY 972126)	<p>The footpath you have just walked along is part of the Pennine Way. At Cardwell Bridge two rivers meet – the River Greta and the Sleightholme Beck. Mellwaters means the ‘meeting of the waters’. Complete activity 2 on Student resource Sheet 1.</p>
3. Sheep fold (GR: NY 969125)	<p>At the sheepfold there is evidence of a Romano-Saxon settlement indicating that this area has been settled for 2000 years. There is evidence of even earlier settlement around East Mellwaters with both Bronze Age (2300 BC – 700BC) and Iron Age (700BC – AD43) remains. Complete activity 3 on Student Resource Sheet 1.</p>
4. Barney Scar (GR: NY 965121)	<p>The river cliff at this point shows the rock types of the area. The rocks in the river cliff were laid down in the Carboniferous Period 350 - 290 million years ago (m.y.a.) and are sedimentary rocks. You can see limestone in the riverbed and if you look very closely in the rocks of the riverbank there are some small crinoid fossils. The dark crumbly rock in the bottom part of the river cliff is shale and then there are thin beds of sandstone moving up into thicker beds of sandstone. At the very top of the valley side you can see a lighter coloured rock, which is limestone again. The limestone was formed in a shallow tropical sea. Calcium carbonate from the seawater and from the remains of seashells and corals accumulated on the sea floor, eventually hardening into limestone. The shale was formed by mud being deposited in the sea, the sandstones by coarser sand being deposited by rivers. This sequence of limestone, shale and sandstone is repeated throughout the Carboniferous Period. The sequence from limestone to shale and then sandstone is called a ‘cyclothem’. Where the limestone appears again at the top of the valley side a new cycle of deposition is beginning and another cyclothem starting.</p> <p>The bed of the beck is limestone. Limestone dissolves in dilute acid. The river water is a dilute acid and has dissolved any weaknesses or cracks/joints in the rock to produce blocks of limestone that look like a pavement. Use the limestone in the ‘Rock Box’ (sample 7) to show how the rock fizzes when a dilute hydrochloric acid is added to it. It is debatable whether this should be called a limestone pavement as it is in the bed of the river and so processes other than solution weathering are also active. Complete activity 4 a and b on Student Resource Sheet 1.</p>
5. The Trough (GR: NY 966123)	<p>The Trough is the gorge that the Sleightholme Beck runs through. It is a Special Site of Scientific Interest (SSSI) as the exposure of Carboniferous sedimentary rocks (like those seen in the river cliff) is of national geological importance. The gorge also has interesting plants that grow in the limestone crevices and on the ledges. The gorge was probably cut after the last ice age due to melt water and the land rising relative to the sea once the weight of the ice had been removed. Complete activity 5 on Student Resource Sheet 1.</p>
6. West Mellwaters (GR: NY 959124)	<p>Just to the east of West Mellwaters the small stream running off Bowes Moor disappears underground. This feature is a sink hole and is at the junction of the sandstone rocks and the limestone. As the water has dissolved the limestone the stream now disappears to form an underground river.</p> <p>Looking south from West Mellwaters you can see Bowes Moor rising above you. Bowes Moor is also a Site of Special Scientific Interest (SSSI). It is a large area of moorland with important areas of blanket bog with dry and wet heath, acid grassland and wet flushes and ponds. It is internationally important for its moorland bird communities. Complete activity 6 on Student resource Sheet 1.</p>





Location and grid reference	Background information
7. Limekilns (GR: NY 957125)	Limestone was burnt in this limekiln to produce calcium oxide or quicklime. The quicklime powder was put on fields to improve the soil. When mixed with water the quicklime becomes soluble and is absorbed onto the land. Complete activity 7 on Student Resource
8. God's Bridge (GR: NY 957125)	<p>God's Bridge is the best example of a natural limestone bridge in England. God's Bridge has developed where the River Greta crosses an outcrop of limestone. It is bedrock spanning a cave 12m long, 2m high and 4m wide. The river Greta flows onto limestone a few hundred metres above the bridge and has developed a series of caves below the valley floor. At God's Bridge there has been some collapse of the cave roof upstream but the bridge itself remains. Downstream of the bridge there is a rocky gorge that represents the unroofed continuation of the cave. A further cave system has developed below the current valley floor and part of the river's flow now passes through this lower cave system, disappearing down sink holes 500m upstream of the bridge.</p> <p>God's Bridge is the last surviving relic of a valley floor cave system. It is possible that downstream of the bridge the cave may have been unroofed with the help of glacial plucking. Complete activity 8 on Student Resource Sheet 1.</p>
9. The River Greta (GR: NY 962126)	Depending on the water levels in the river and the weather conditions, different limestone features can be seen. In very low flow conditions water can be seen disappearing down sink holes in the riverbed at various places between God's Bridge and the Pack Horse Bridge. This is particularly true beyond the third field boundary. After heavy rain resurgent streams can be seen issuing out of the banks of the river where there is no stream in the field above. Just before the river cliff to the west of the Pack Horse Bridge there is a large resurgent stream that issues from the south bank of the river. It is thought that this is the water from the River Greta rejoining the river channel from the cave system. Complete activity 9 on Student Resource Sheet 1.

FOLLOWING UP THE FIELDWORK

1. Limestone scenery at East Mellwaters Farm

Complete the table given on Student Resource Sheet 4.

2. Sustainable development at East Mellwaters Farm

Complete Student Resource Sheet 5.

3. An enquiry into the limestone pavement at Slapstone Bridge, North Stainmore

Presenting and describing your results

- On graph paper or using the computer draw a graph with the distance along the limestone pavement transect in metres on the x-axis and a scale in centimetres on the y-axis that will be appropriate to plot the long axis of the clints and the width and depth of grykes on. Leave room above the graph to present the data on vegetation cover.
- Calculate the mean long axis of the clints and the mean gryke width and depth for each site.
- Plot your calculations for each quadrat site on your graph.
- Above these graphs draw a pie graph for each site to show the percentage vegetation cover.
- Put the data for the direction of the longest axes of

the clints into the table on Student Resource Sheet 6. 6. Use the data in the table on Student Resource Sheet 6 to draw a rose diagram.

Analysing your results

Describe what your results show. From your results accept or reject the hypotheses you set up.

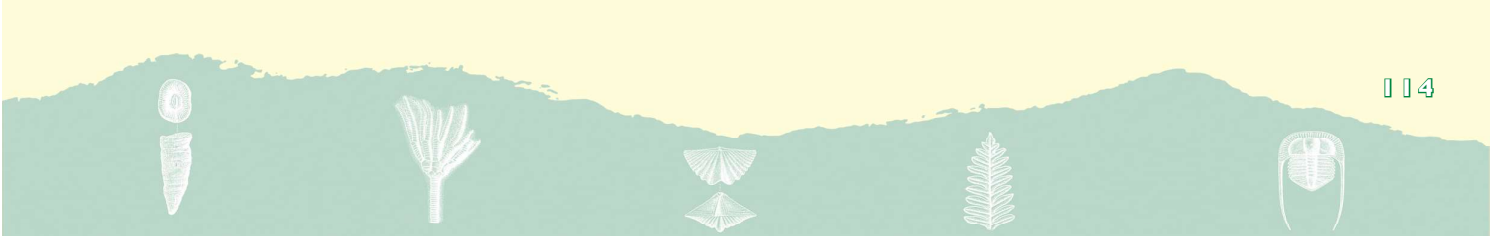
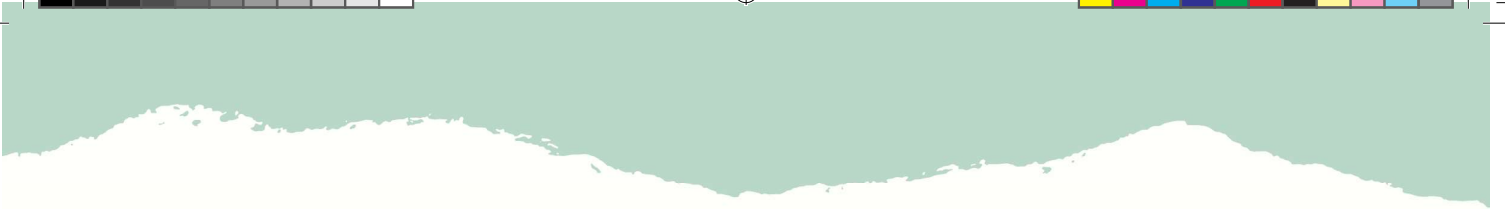
Summarising your results

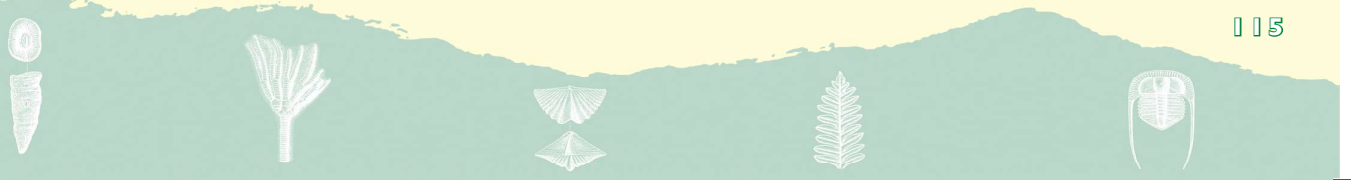
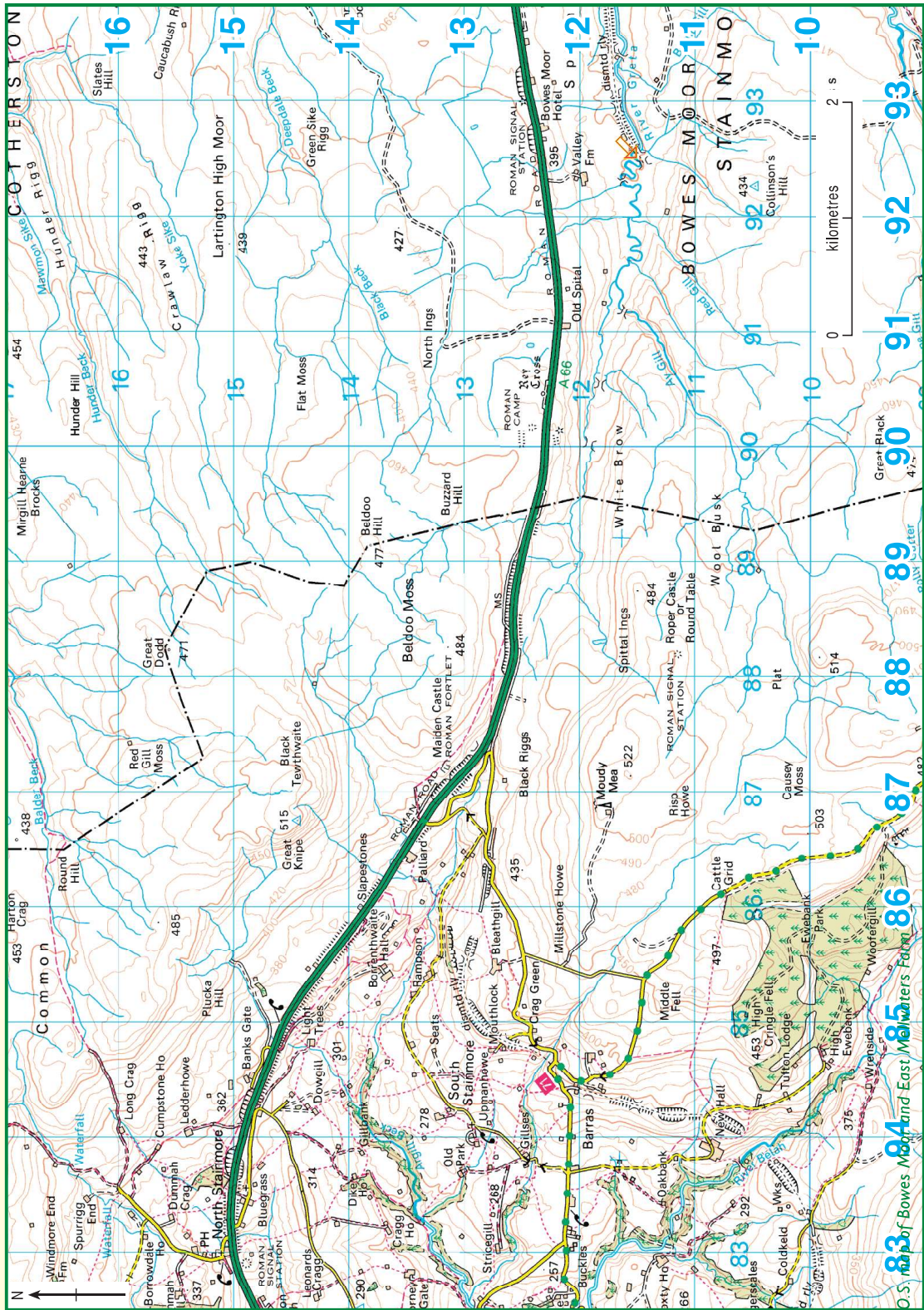
From your results summarise the following:

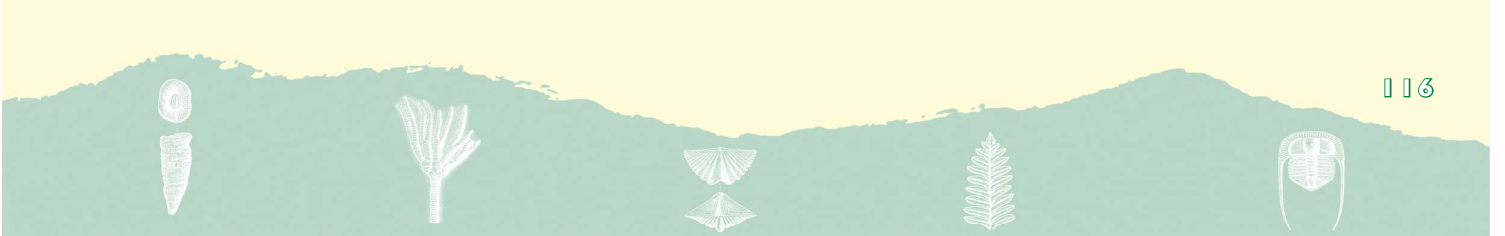
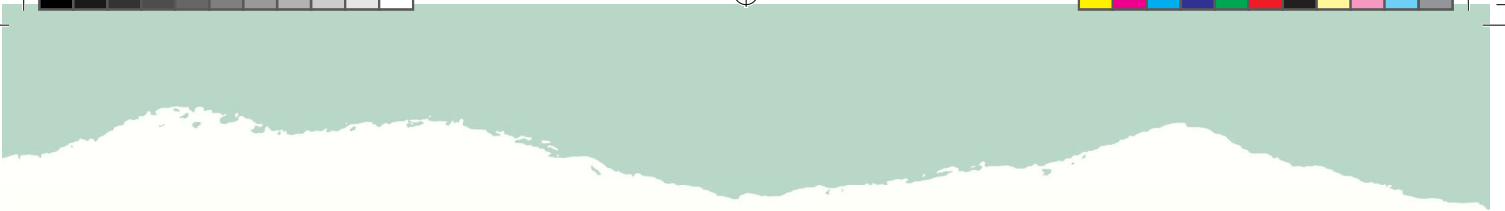
- Do clints vary in size across the limestone pavement? Explain your answer.
- Do grykes vary in width and depth across the limestone pavement? Explain your answer.
- Does the direction of the long axes of the clints vary? Explain your answer.
- Does vegetation cover vary across the limestone pavement? Does the amount of vegetation cover increase with the increasing size of grykes? If so why should this be the case?

Additional work

- Use the case study of the Marble Arch Caves European Geopark to look at the features of another limestone area.
- Use the 'Rock Box' to explore the characteristics of limestone, shale and sandstone and to take a closer look at the fossils found in the limestone.







Ordnance Survey Map Symbols

ROADS AND PATHS

	Motorway
	Dual carriageway
	Main road
	Secondary road
	Narrow road with passing places
	Road under construction
	Road generally more than 4m wide
	Road generally less than 4m wide
	Other road, drive or track, fenced and unfenced
	Path

RAILWAYS

	Multiple track
	Single track

PUBLIC RIGHTS OF WAY

	Footpath
	Bridleway

BOUNDARIES

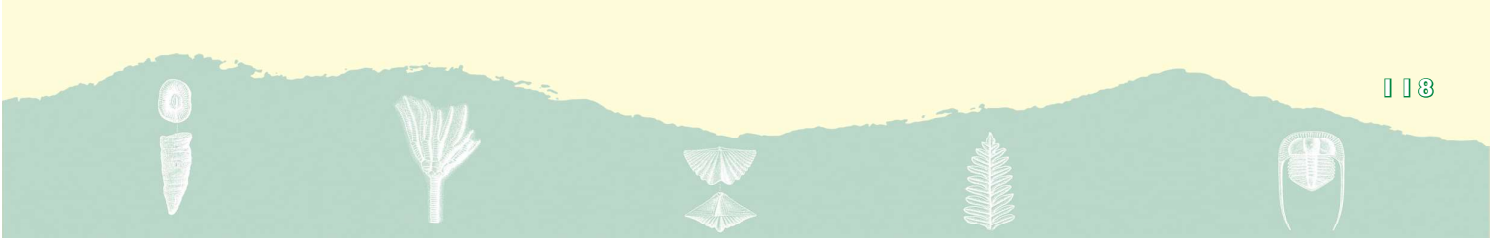
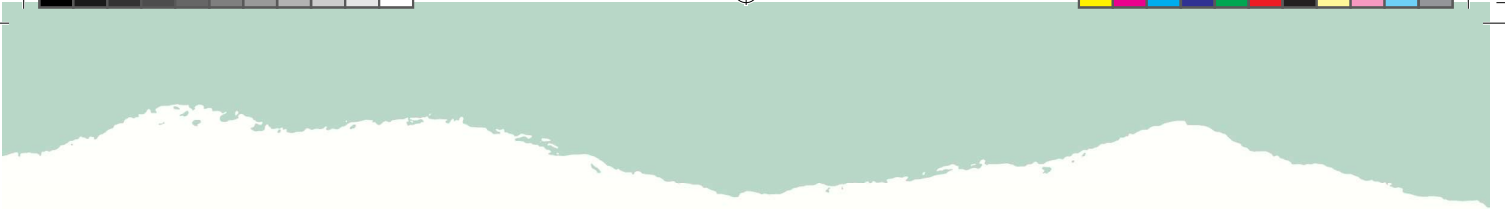
	National
	County (England)
	Civil Parish (CP)
	National Park boundary

SELECTED TOURIST AND LEISURE INFORMATION

	Parking
	Information centre
	Public convenience
	Telephone
	Campsite / caravan site
	Golf course or links
	Public house
	Walks
	Viewpoint
	Picnic site
	Country park

GENERAL FEATURES

	Place of worship
	Building
	Bus or coach station
	Triangulation pillar
	Windmill
	Boundary post / stone
	Clubhouse
	Footbridge
	Monument
	Post Office
	Police station
	School
	Town hall



Limestone Landscapes on Bowes Moor and Sustainable Development

Student Information Sheet 1

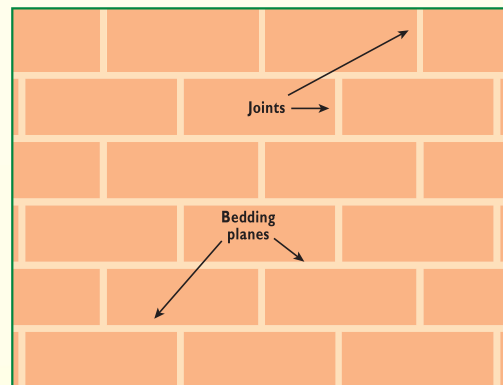
LIMESTONE PROCESSES AND FEATURES

One of the main rock types in the North Pennines is Carboniferous limestone. This limestone was formed during the Carboniferous Period (350 – 290 million years ago), when the landmass that is now Britain was close to the equator. The limestone contains many fossils, including corals, crinoids and brachiopods (look for these fossils in the 'Rock Box'), which indicate that the limestone was formed in a warm, clear, shallow tropical sea. Limestone consists of at least 80% calcium carbonate and is made up of the shells of sea creatures and calcium carbonate, which was in solution in the seawater. This rock type develops its own particular type of scenery and landforms, known as KARST, as a result of 2 main characteristics. The characteristics of limestone that produce karst scenery are:

1. Limestone is a well-bedded and jointed rock. Limestone is formed in thick beds separated by almost horizontal **BEDDING PLANES**. The rock also has vertical cracks called **JOINTS**.

These bedding planes and joints make the limestone pervious but not porous, meaning that water can pass along the bedding planes and down the joints, but not through the body of the rock itself.

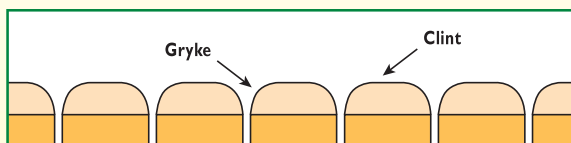
2. The calcium carbonate in the limestone is soluble in acid. Rainwater contains carbon dioxide in solution, which produces a carbonic acid. This weak acid dissolves the limestone especially at weaknesses in the rock such as along bedding planes and joints. This process is called solution weathering or carbonation.



Limestone scenery – karst

Carboniferous limestone landscapes have their own unique scenery and landforms known as karst. Many karst landforms can be seen in the North Pennines, especially at East Mellwaters Farm. The main karst features include:

1. **Limestone pavement** – This is an area of flat exposed limestone. The exposed limestone represents a bedding plane where the surface soil, vegetation and weathered rock have been removed by glacial activity.



Once exposed the joints in the limestone are enlarged by acid rainwater. The enlarged joints are called **GRYKES** and the blocks that remain in between are called **CLINTS**. An example is the limestone pavement at Slapstone Bridge, North Stainmore, Cumbria.

2. **Drainage features** – Limestone areas have distinctive drainage features. Where rivers flow onto limestone they disappear underground down holes called **sink** or **swallow holes**. An example is seen at West Mellwaters Farm. Once underground, the river follows enlarged vertical joints, called **potholes**, and runs along bedding planes. Where solution weathering is most active caves form underground that are later enlarged by the river flowing through them. The river continues to flow underground in the limestone until the underlying rock type changes. The river will then re-appear on the surface again as a **resurgence** or **resurgent stream**.

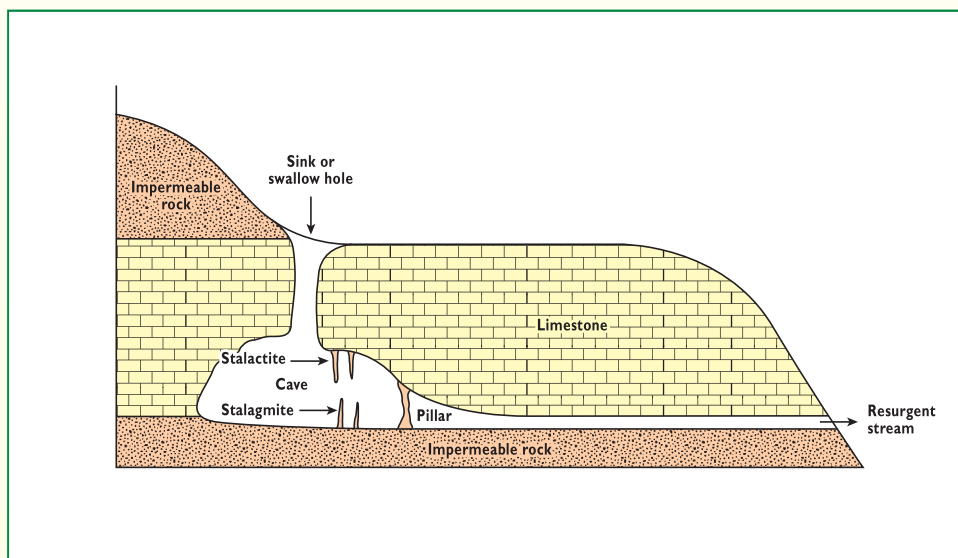
Sometimes a cave system develops below the valley floor and the riverbed is dry as the river is flowing underground. The roof of the cave system can collapse but spans of limestone may be left across the



river as **natural bridges**. An example is God's Bridge, County Durham. The river either side of a natural bridge may run through a small gorge that represents the river running through the unroofed cave system.

3. **Gorge** – Where a series of underground caves become too large to support the rock above them, then the limestone will collapse to form a gorge.

4. **Stalactites and stalagmites** – The water flowing underground in the limestone is saturated with calcium carbonate due to solution weathering. However, when the water reaches a cave much of the calcium carbonate bubbles back out of solution and is deposited on the roof or floor of the cave. Calcium carbonate deposits hanging from the roof of the cave are called **stalactites** and deposits growing up from the floor are called **stalagmites**. Sometimes stalactites and stalagmites can join to form a **pillar**.

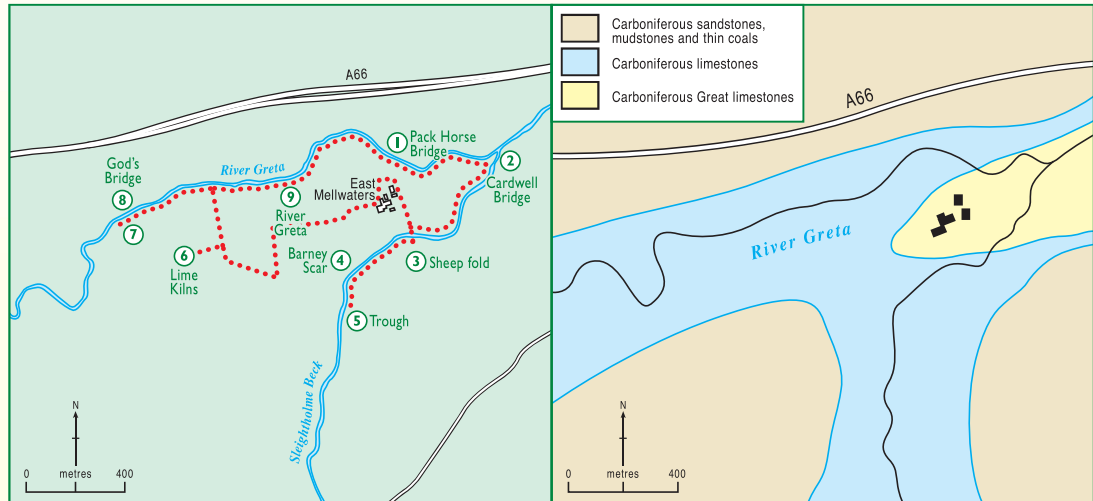




Limestone Landscapes on Bowes Moor and Sustainable Development

Student Resource Sheet 1

LIMESTONE SCENERY AND FEATURES OF INTEREST AT EAST MELLWATERS FARM



1. Describe East Mellwaters Farm

.....

.....

.....

.....

2. Which two rivers join at Mellwaters or the 'meeting of the rivers'?

.....

.....

3. How long has this area been farmed?

.....

.....





4a. Draw a sketch of the river cliff and label the main rock types:

4b. Sketch the limestone pavement and label the clints and grykes?

5 What is the trough and why is it important?

.....

.....

.....





6. Using the geology map to help you describe how sink holes are formed:

.....

.....

.....

7. What were lime kilns used for?

.....

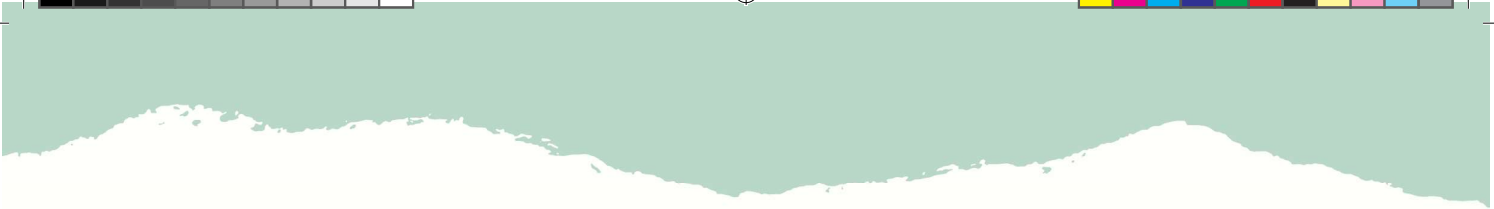
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8. Sketch God's Bridge and label the **limestone bedrock bridge**, **gorge - unroofed cave** and **River Greta**:

9. On the map mark any resurgent streams with a **RS** and any strike holes in the river bed with a **SH**.





Limestone Landscapes on Bowes Moor and Sustainable Development

Student Resource Sheet 2

EAST MELLWATERS FARM - AN EXAMPLE OF SUSTAINABLE DEVELOPMENT

Sustainable development

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Farming, like any other industry, needs to become more sustainable by ensuring it is economically viable, is contributing to the conservation and environmental enhancement of the countryside and is providing for public access and understanding.

Economically, this may mean that farms need to diversify or find other sources of income rather than just relying on food production. For example, a farm may also provide opportunities for tourism through the provision of bed and breakfast accommodation or offer agricultural services to other farmers. Farmers also need to be environmental stewards conserving the wildlife or biodiversity of the farm, maintaining or enhancing the landscape and protecting the historic environment and natural resources. Socially, farmers must maintain current access and where desirable, extend access and promote understanding of the countryside through leaflets, walks and interpretation.

East Mellwaters Farm

East Mellwaters Farm is contributing to sustainable development through a range of economic, environmental and social improvements to the farm. Use the key below to record the improvements on the base map on the opposite side of this sheet. Additional notes can be made around the map where necessary.

Key to improvements at East Mellwaters Farm

Environmental



Tree planting



Bird boxes



Dry stone walls maintained



Buildings sympathetically renovated



Hedges planted or maintained



Historic feature conserved

Economic



Self-catering accommodation



Disabled accommodation



Farming

Social



Public right of way



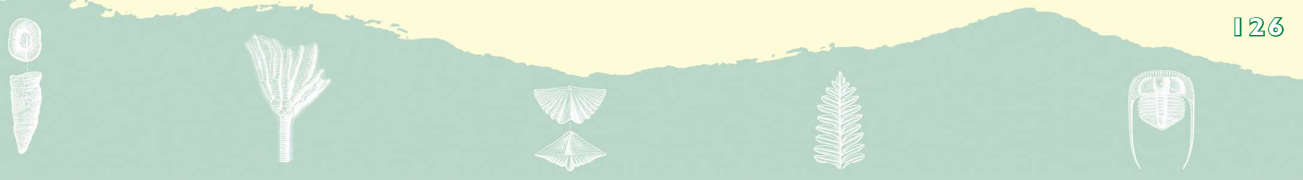
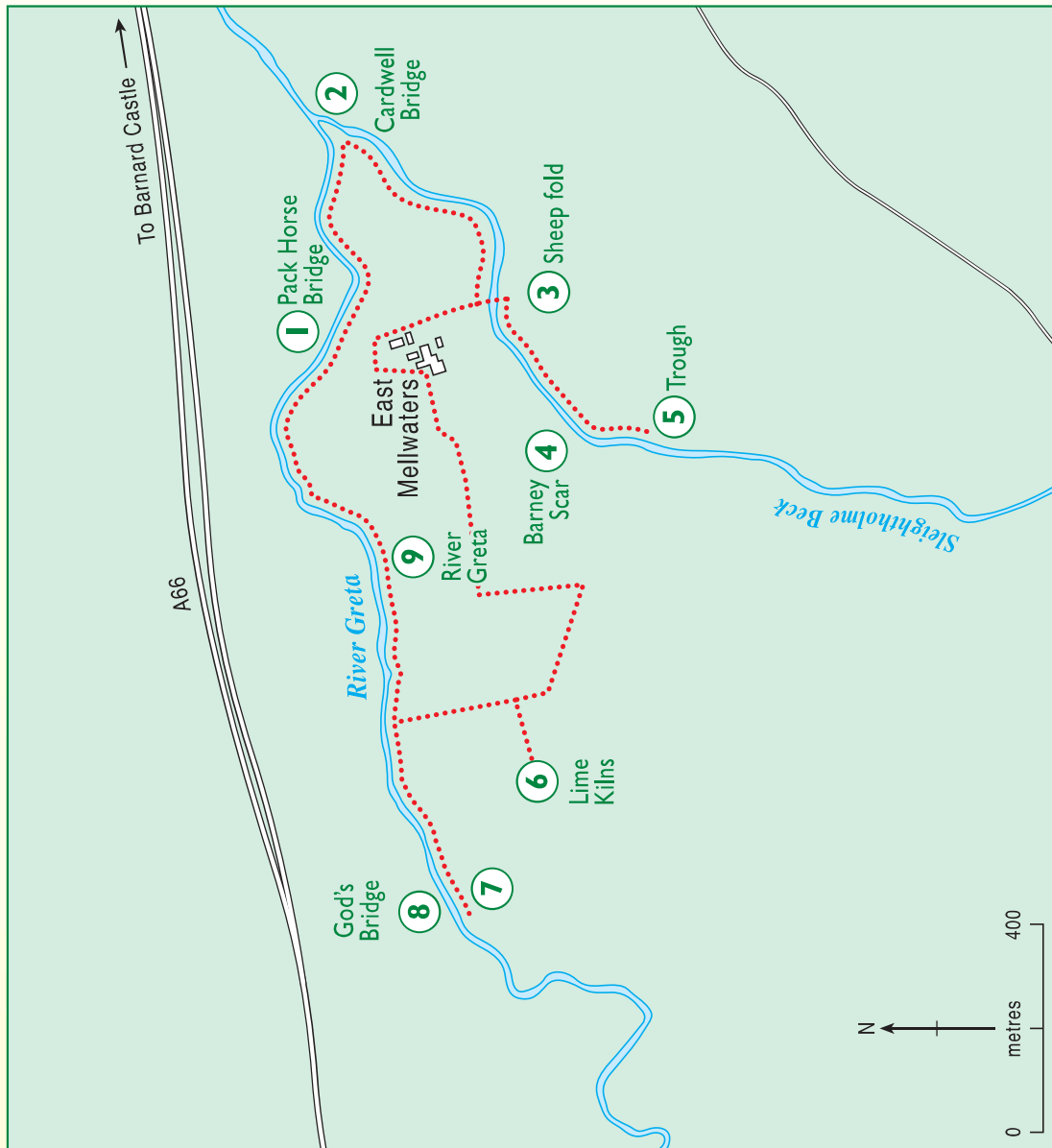
Permissive path



Wheelchair accessible path



Walks leaflet (mark at starting point)





Limestone Landscapes on Bowes Moor and Sustainable Development

Student Information Sheet 2

AN ENQUIRY INTO THE LIMESTONE PAVEMENT AT SLAPESTONE BRIDGE, NORTH STAINMORE

Aim

The aim of this enquiry is to see if the features of the limestone pavement at Slapestone Bridge vary across its surface.

Questions to ask?

- Where is the vegetation found on the limestone pavement?
- Do the clints vary in size?
- Does the direction of the clint vary?
- Do the grykes vary in width?
- Do the grykes vary in depth?

(Turn these questions into hypotheses and record them on Student Resource Sheet 3).

Methods

1. In small groups lay out transects across the limestone pavement from west to east. The first group will be at the top of the pavement and the other groups in positions below.

2. Set up transects from west to east across the limestone pavement using a 50m tape. The recordings you are going to make will be every 5m along the tape. You may need to move the tape if your section of the limestone pavement is more than 50m across.

3. Every 5m along the tape place a 1m x 1m quadrat on the ground. In each quadrat record:

- Percentage of the quadrat covered by vegetation
- Length of the long axis of each clint within the quadrat
- Direction of the long axis of each clint
- Width of each gryke in the quadrat
- Depth of each gryke in the quadrat

Equipment

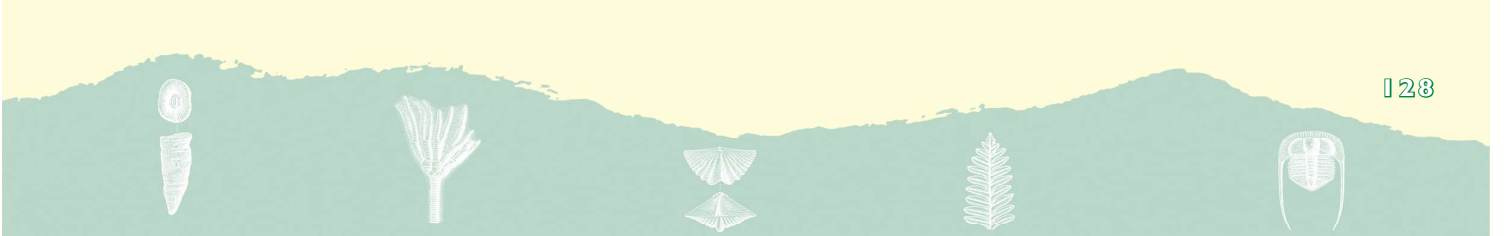
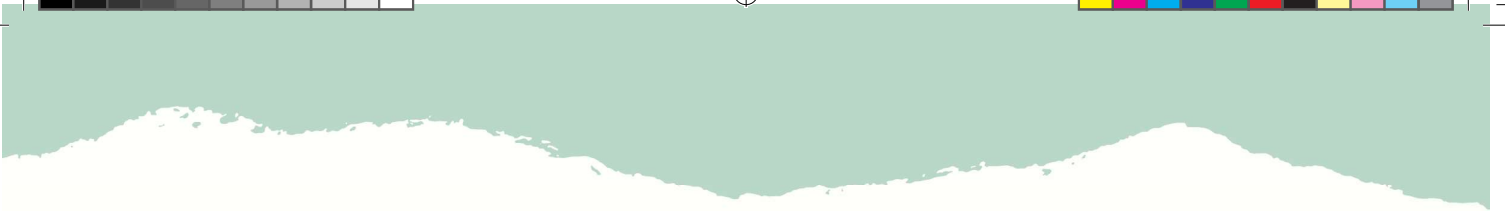
The following equipment will be required:

- 50m tape
- 1m x 1m collapsible quadrat
- Metre rule
- Compass

Results

Record your results on Student Resource Sheet 3.







Limestone Landscapes on Bowes Moor and Sustainable Development

Student Resource Sheet 3

LIMESTONE PAVEMENT RECORDING SHEET

Hypothesis

Use the questions identified on Student Information Sheet 2 to give 5 hypotheses below:

- a)
- b)
- c)
- d)
- e)

Results

Distance along transect (m)	Percentage cover of vegetation	Length of long axis of clints (cm)	Direction of long axis of clints	Width of grykes (cm)	Depth of grykes (cm)
0					
5					
10					
15					
20					
25					
35					
40					
45					
50					



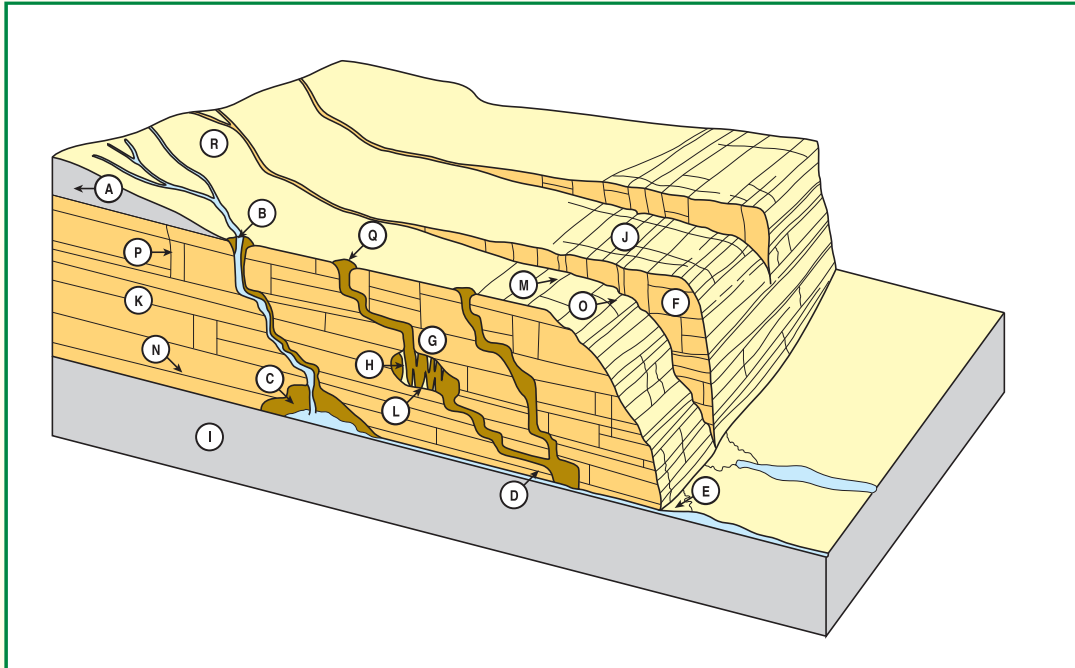
Distance along transect (m)	Percentage cover of vegetation	Length of long axis of clints (cm)	Direction of long axis of clints	Width of grykes (cm)	Depth of grykes (cm)
55					
60					
65					
70					
75					
80					
85					
90					
95					
100					

Limestone Landscapes on Bowes Moor and Sustainable Development

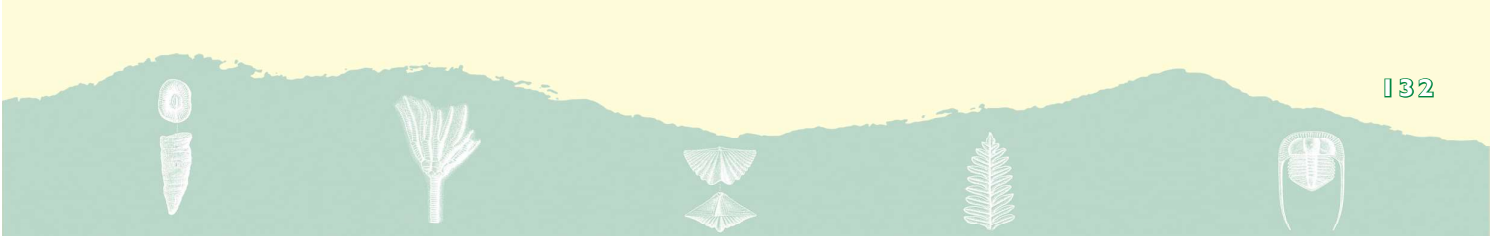
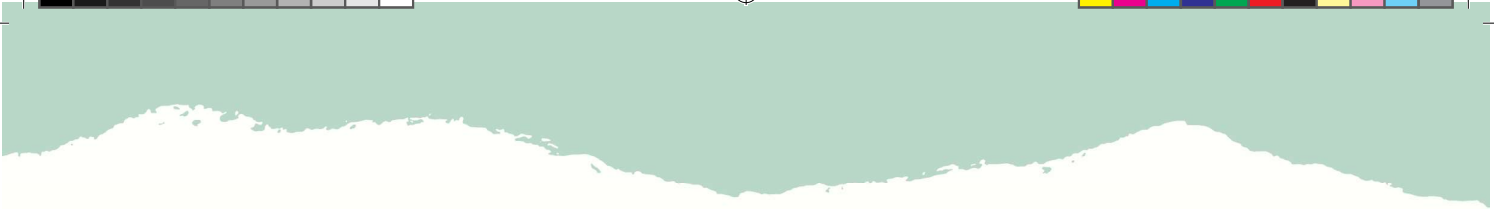
Student Resource Sheet 4

LIMESTONE SCENERY AT EAST MELLWATERS FARM

Using the information gathered at East Mellwaters Farm, name the features A-R shown in the diagram below:



Letter	Name of feature	Letter	Name of feature
	Impermeable rock		Surface river
	Impermeable rock		Resurgence
	Limestone - a pervious rock		Pothole
	Bedding planes		Cave
	Joints		Stalactite
	Limestone pavement		Stalagmite
	Clints		Pillar
	Grykes		Underground river
	Sink hole or swallow hole		
	Gorge		



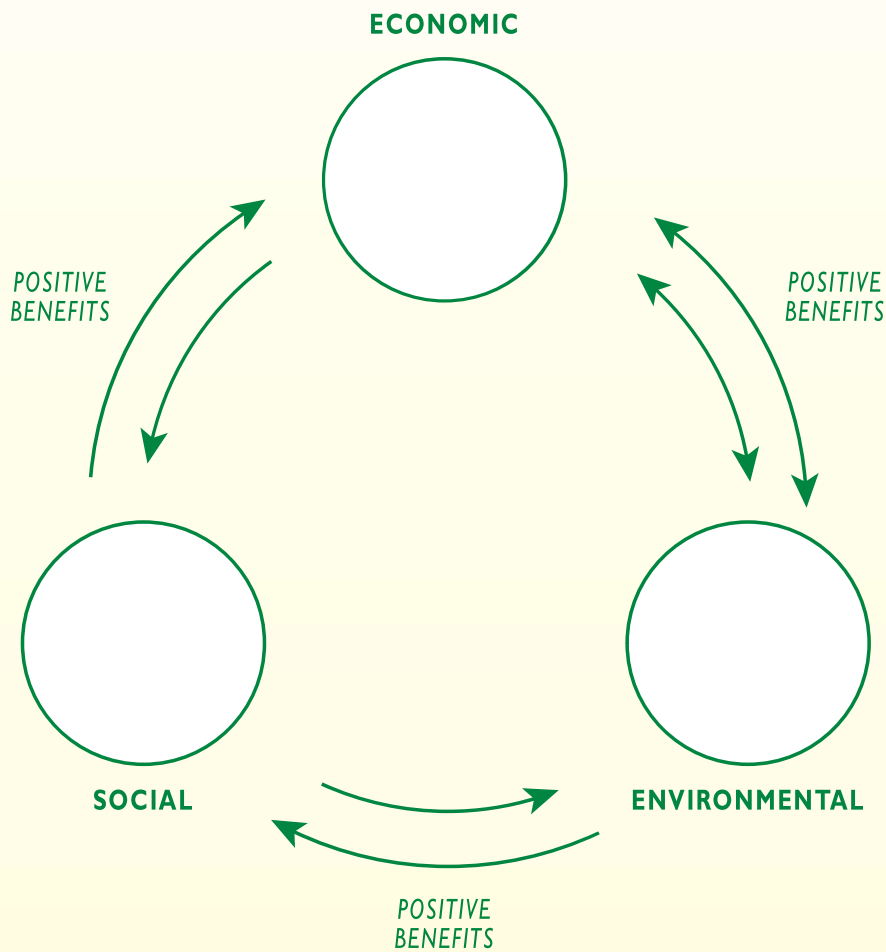


Limestone Landscapes on Bowes Moor and Sustainable Development

Student Resource Sheet 5

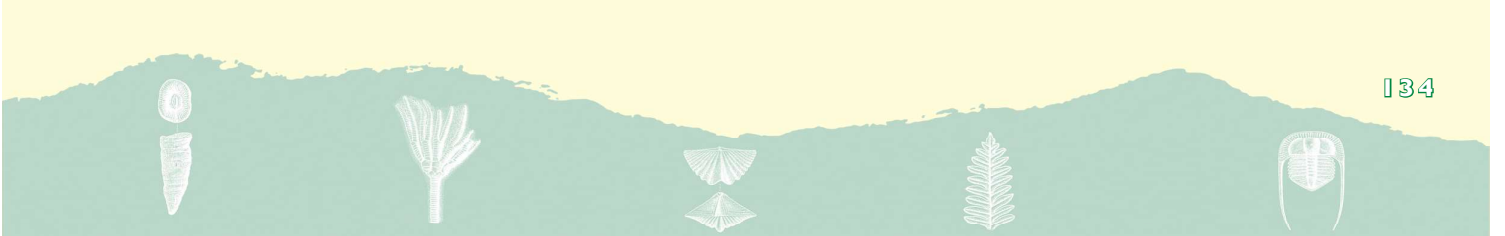
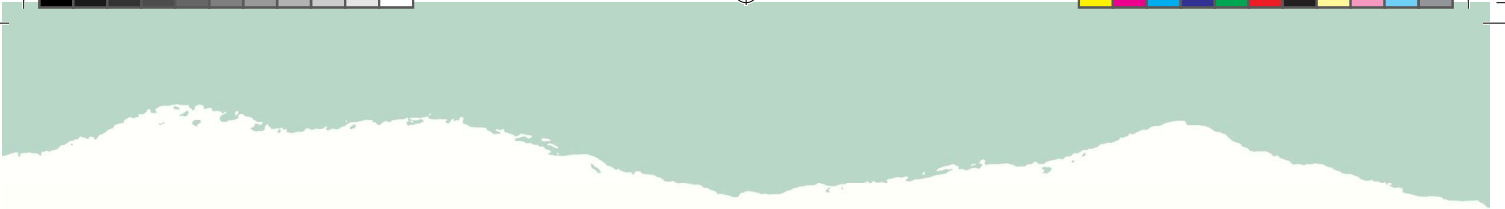
SUSTAINABLE DEVELOPMENT AT EAST MELLWATERS FARM

In the three circles below add the improvements that have been made to East Mellwaters Farm that will enable the farm to become more sustainable. Divide your answers into economic, environmental and social factors as indicated by the circles.



The arrows on the diagram indicate that social improvements on the farm can benefit the economy of the farm and the environment, economic improvements can have environmental and social benefits and improvements to the environment can have economic and social benefits. Using the diagram you have produced above, describe how each improvement at East Mellwaters Farm will have benefits for the other areas of the farm. For example, how have the improvements for wildlife helped the economic sustainability of the farm?







Limestone Landscapes on Bowes Moor and Sustainable Development

Student Resource Sheet 6

AN ENQUIRY INTO THE LIMESTONE PAVEMENT AT SLAPESTONE BRIDGE, NORTH STAINMORE

Direction of long axis of clint (degrees)	Tally	Total number of clints	Percentage of clints for each category
0 - 10 / 180 - 190			
10 - 20 / 190 - 200			
20 - 30 / 200 - 210			
30 - 40 / 210 - 220			
40 - 50 / 220 - 230			
50 - 60 / 230 - 240			
60 - 70 / 240 - 250			
70 - 80 / 250 - 260			
80 - 90 / 260 - 270			
90 - 100 / 270 - 280			
100 - 110 / 280 - 290			
110 - 120 / 290 - 300			
120 - 130 / 300 - 310			
130 - 140 / 310 - 320			
140 - 150 / 320 - 330			
150 - 160 / 330 - 340			
160 - 170 / 340 - 350			
170 - 180 / 350 - 360			



