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Fieldwork sites in Teesdale, County Durham

- **Science and geology**
  Bowlees: Let's Rock!: The Carboniferous Period of Teesdale
  Cauldron Snout: Baked Rocks

- **Geography**
  River features and processes in Upper Teesdale
  Limestone landscapes on Bowes Moor and sustainable development

- **Geo-activity Trails**
  Holwick and Low Force Geo-activity trail
  Cow Green Geo-activity trail

- **Signposting of places of interest and information in Teesdale**

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Science and Geology

ORGANISATIONAL DETAILS

Aim

1. To describe and identify rocks on the basis of their characteristics, including appearance, texture, colour and occurance;
2. To understand geological processes that can alter rocks and;
3. To identify how different rock types can be used to reconstruct ancient environments hundreds of millions of year old.

Target Group

Key Stage 3 and 4

Location

This fieldwork day starts at the Bowlees, to the west of the hamlet of Newbiggin in upper Teesdale. There are 4 main fieldwork sites, Bowlees Quarry (GR: NY 908284), Gibson's Cave (GR: NY 906285), Low Force (GR: NY 903278) and 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 and the car park at High Force.

Practical Details

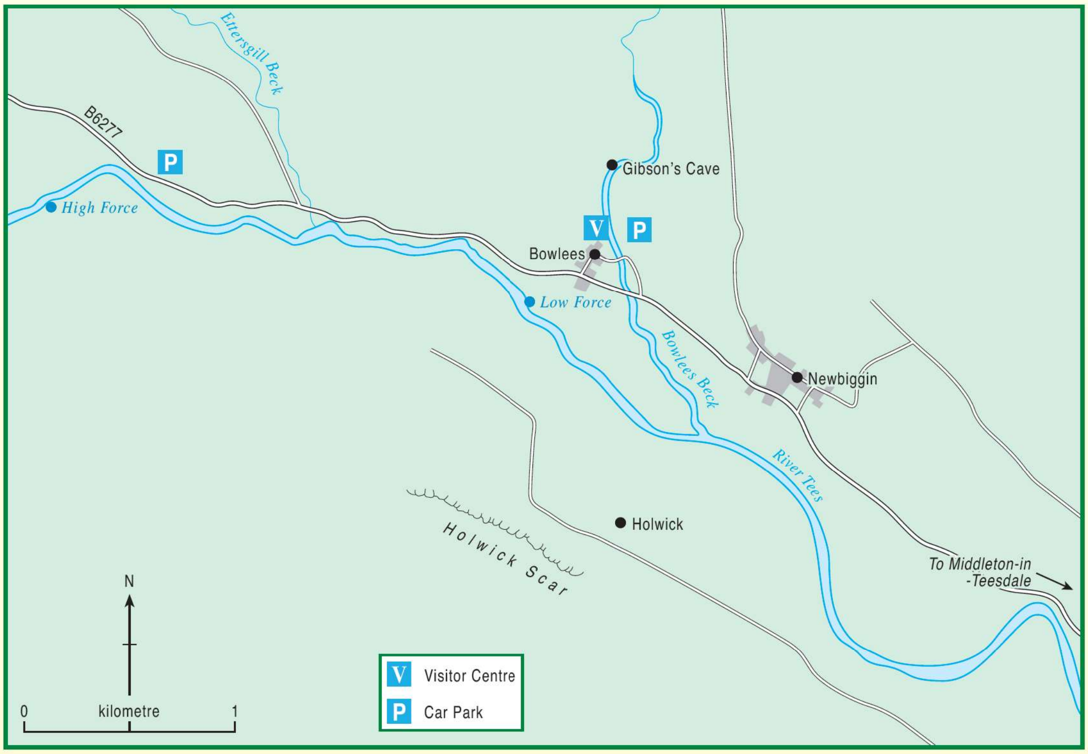
- Parking – There is free parking at Bowlees. Parking for coaches is on the main road (GR: NY 905281). The three river sites and Gibson's Cave are within easy walking distance. There is a charge for the car park at High Force.
- Charges – There are no charges at Bowlees but there is an entrance charge for the waterfall at High Force.
- Toilet facilities – There are toilets at Bowlees and at High Force
- Picnic areas – There are picnic areas at both Bowlees and High Force.
- Useful map – Ordnance Survey 1:25 000 Explorer OL31 North Pennines Teesdale and Weardale.

Safety Issues:

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

Low Force and High Force: Let's Rock!

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 by 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.

Plan of activities

- STOP A-C. These stops are focused on Bowlees and Gibson's Cave. They provide good starter activities and identification of rock types (~60 mins).
- Follow the path from Bowlees car park to Low Force.
- Stop D & E. These two stops are based at Low Force waterfall and around the Wynch Bridge. Both stops investigate the Whin Sill and igneous rock types (~40 mins).
- Cross the Wynch Bridge and follow the path on the south side of the River Tees to Stop F (~40 mins).
- STOP F. Viewing stop of the landscape and the occurrence of a geological fault delimiting the first part of the gorge along the River Tees (~10 mins).
- Walk over the bridge and follow the path to High Force at Stop G (~25 mins).
- STOP G. Follow path to High Force and the viewing platform. Use the activity sheet to focus observations on the different rock layers and stratigraphy that makes up the waterfall (~40 mins).

Low Force and High Force: Let's Rock!

Let's Rock! The Carboniferous of Teesdale

BACKGROUND INFORMATION

Between 350 and 290 million years ago the landmass that was to become the UK was positioned at the Equator. The North Pennines, during this geological time period known as the **Carboniferous** was periodically covered by large rainforests, vast river deltas and warm tropical seas that hosted an abundant fauna. The Carboniferous Period is named after the presence of coal (carbon) within much of the coal succession worldwide. No coal has been found at Bowlees but the sections are still very important for understanding the evolution of the North Pennines.

During the early part of the Carboniferous period, much of the area was submerged beneath warm tropical seas, where marine animals including, corals, sponges, crinoids (sea lilies) and molluscs flourished. Their remains are now found preserved in the limestones. Periodically large deltas built out into the sea where the sand, silt and mud settled out on the sea floor, burying the marine life and eventually hardening into sandstone, siltstone and mudstone. Over millions of years this pattern of limestone formation, followed by muds and sands of deltas produced regular and repeating cycles. This can be seen throughout the Bowlees and High Force localities.

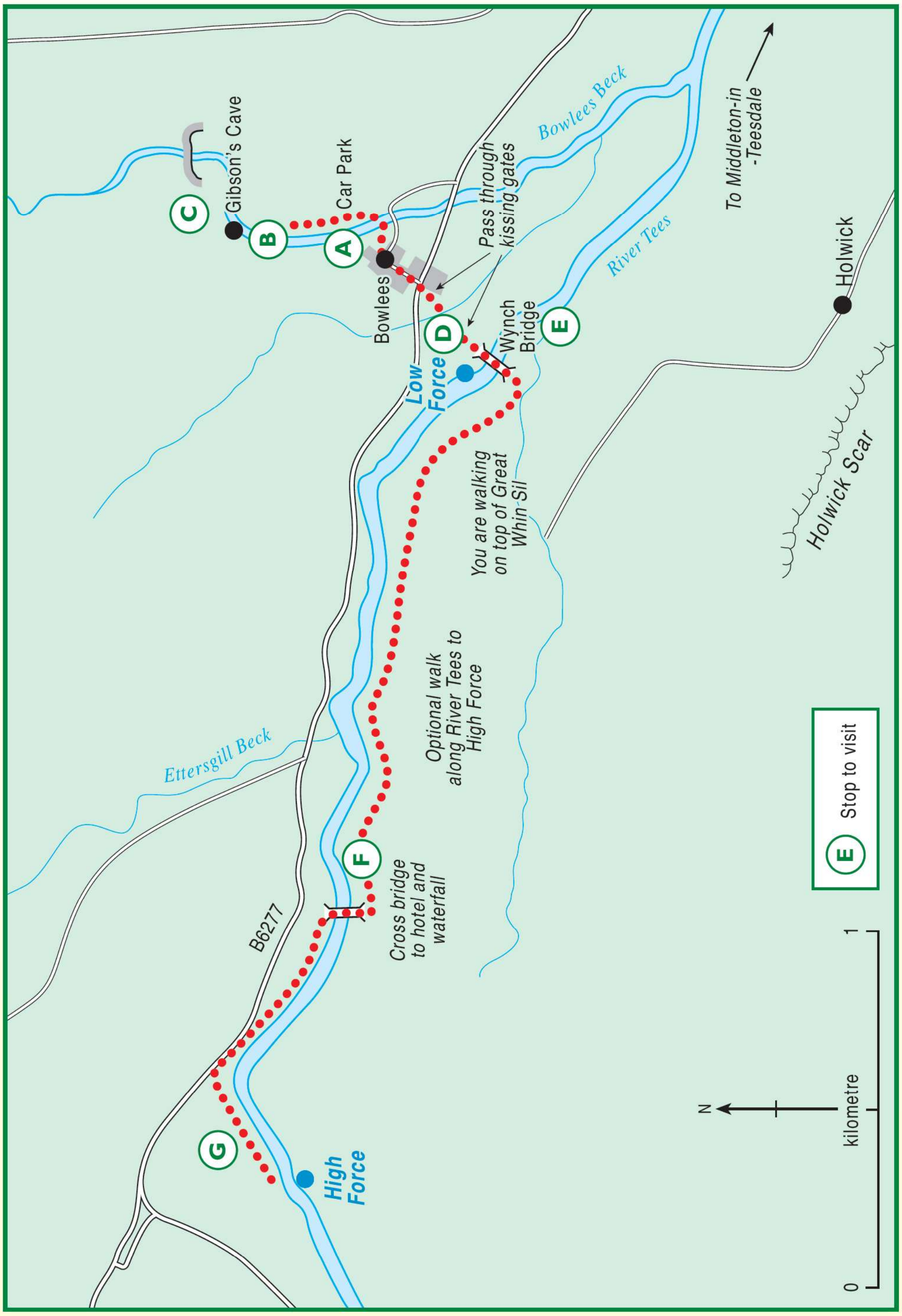
At the end of the Carboniferous Period (about 295 million years ago), the Earth's crust in the North Pennines experienced stretching and thinning due to continental plate movements. This was followed by the up-welling of hot magma (>1100oc) that flowed between the layers of limestone, sandstone and shale where it cooled and crystallised to form a black hard rock known as **dolerite** (see photo of rock). During the intrusion of the dolerite into the surrounding rocks it 'baked' the rocks to form weakly metamorphosed sediments. These are best seen at Low Force. Furthermore during the cooling of the dolerite prominent vertical features developed called columnar jointing and can be easily seen at High Force. The term Whin Sill is applied for the intrusion of the black dolerite in Northern England. Geologists describe sills as horizontal intrusions of igneous rocks. This differs to a dyke that is a vertical intrusion of igneous rock and usually much smaller (e.g. Armathwaite Dyke in Cumbria).

As the Whin Sill is more resistant than the surrounding rocks, it forms prominent escarpments in the North Pennine landscape, such as Holwick Scar and High Cup Nick. Rivers that cross the sill produce spectacular waterfalls, such as High Force (see photo) and Cauldron Snout.

High Force is a classic example of how waterfalls evolve with a hard resistant rock, the Whin Sill, undercut by an underlying softer sedimentary rock, sandstone. This undercutting slowly leads to the retreat of the waterfall producing the long gorge you walk along up to the present position of the waterfall.

Low Force and High Force: Let's Rock!

Student Information Sheet



Low Force and High Force: Let's Rock!

Student Resource Sheet 1

LET'S ROCK!

Aims of exercise:

1) To analyse different rock types in the field and understand how they formed
2) To recognise the effects of an igneous intrusion (Whin Sill) on sedimentary rocks
3) To understand the geological time period called the Carboniferous between 350 and 290 million years ago.

What you need: a pencil, colouring pencils (blue, orange and black), a hand lens and about 4 hours of time

Where you go: Follow the map (Bowlees-1) and answer the questions about each of the geological stops (A to G).

For stops A-C you will also need sheets Bowlees-2, Rock Test and data sheets, cyclothem log sheet, and fossils identification sheet

Use the map to find each of the different stops. At each stop identify the rock types and complete the rock data sheet. As you make your way from Stops A to C consider how the sedimentary rocks are laid on top of each other and colour in the appropriate sections of the graphic log sheet.

Cross over bridge directly above the toilet block and use rock exposures along stream bank.

STOP A: Small exposures of Carboniferous sedimentary rocks along the stream bank.

Use the rock tests to identify the sedimentary rocks and colour in the appropriate section of the graphic log with the correct rocks.

Walk across open grassy area to edge of quarry. Make sure to follow the designated paths as this area contains many protected species of plant.

STOP B: Quarry

Why is the quarry floor so important for rare species of plants?

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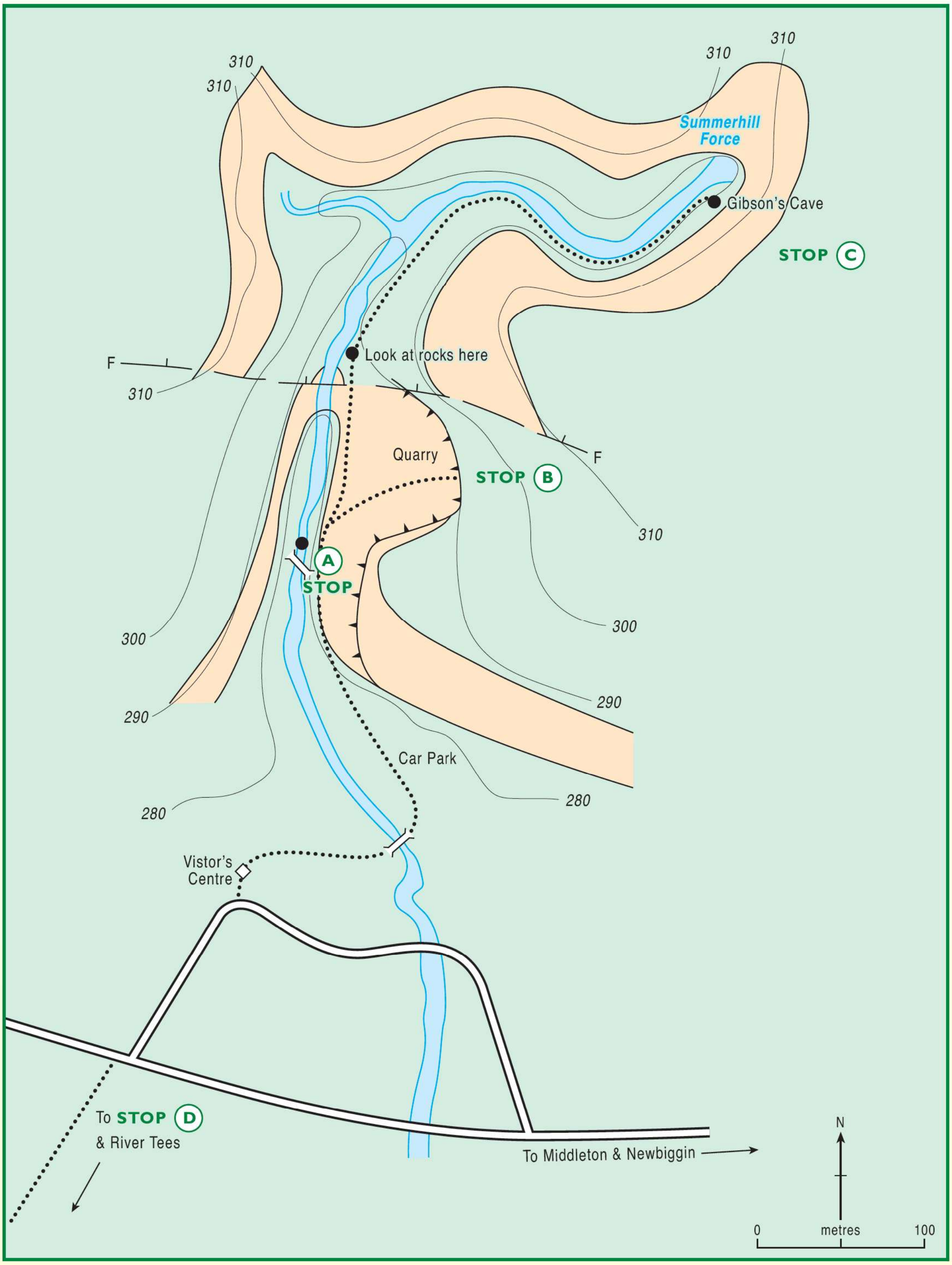
Use the rock tests to identify the light grey coloured sedimentary rock and colour in the appropriate section of the graphic log with the correct rock.



Geological map of Bowlees and Gibson's Cave

Fossils found in rocks can tell us what living organisms were like in the past. A fossil is any part of something that once lived, and is now preserved in rock.

Only rarely is the fossil a whole body or plant.

Sometimes fossils can be just a single bone, part of a shell or even a footprint.

Fossils are found most commonly in sedimentary rocks and in particular limestones.

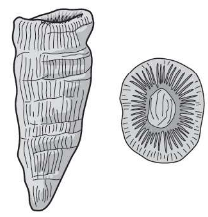
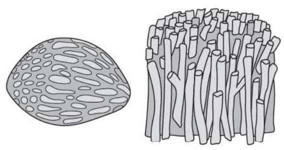
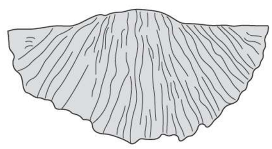
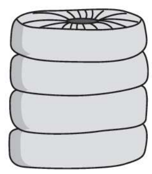
Draw at least one fossil you find in the rocks. Use the fossil identification sheet to help recognise the fossil and any others.

Sketch of a fossil found in Bowlees Quarry. Limestones are often full of fossils but not always obvious. Remember to include a scale on your sketch to show the size of the fossil.

Why do you think there are so few fossils in this sedimentary rock?

FOSSIL IDENTIFICATION SHEET

Fossils found in Limestones

Type of fossil	Name	Description	Sketch	Found
Coral - Solitary	*Dibunophyllum*	Corals live on own		
Coral - Colonial	*Lithostrotion*	Corals live together		
Brachiopods	*Gigantoproductus*	Two shells of different sizes		
Crinoids	*Crinoid ossicles and stems*	Fossilised 'Sea Lillies'. Ossicles are disc shaped segments that make up stalks		

Walk up steps next to stream and stand on viewing platform

Observe the mudstones and sandstones that overlay the rocks seen in the quarry. Colour in the appropriate section of the graphic log

Follow path until you reach the waterfall. Do not climb over wall for safety reasons.

STOP C Summerhill Force – Gibson's Cave

The waterfall at Gibson's Cave has fomed due to harder and more resistant limestone forming the top lip of the waterfall. Underneath the limestone are sandstones and mudstones that are more easily eroded and slowly back cut into the cliff face. Eventually the limestone on top will collapse and the whole waterfall will recede back.

Use the rock tests to identify the sedimentary rocks and colour in the appropriate section of the graphic log with the correct rocks.

The recognition of the different rocks at stops A to C illustrates the sedimentary rocks that form the Teesdale landscape and at Bowlees were deposited in cycles. Such cycles are called **cyclothems** in carboniferous age rocks.

A cyclothem is identified on your graphic log sheet.

What is the sequence of rock types that were laid down on top of each over millions of years to create a cyclothem?

....

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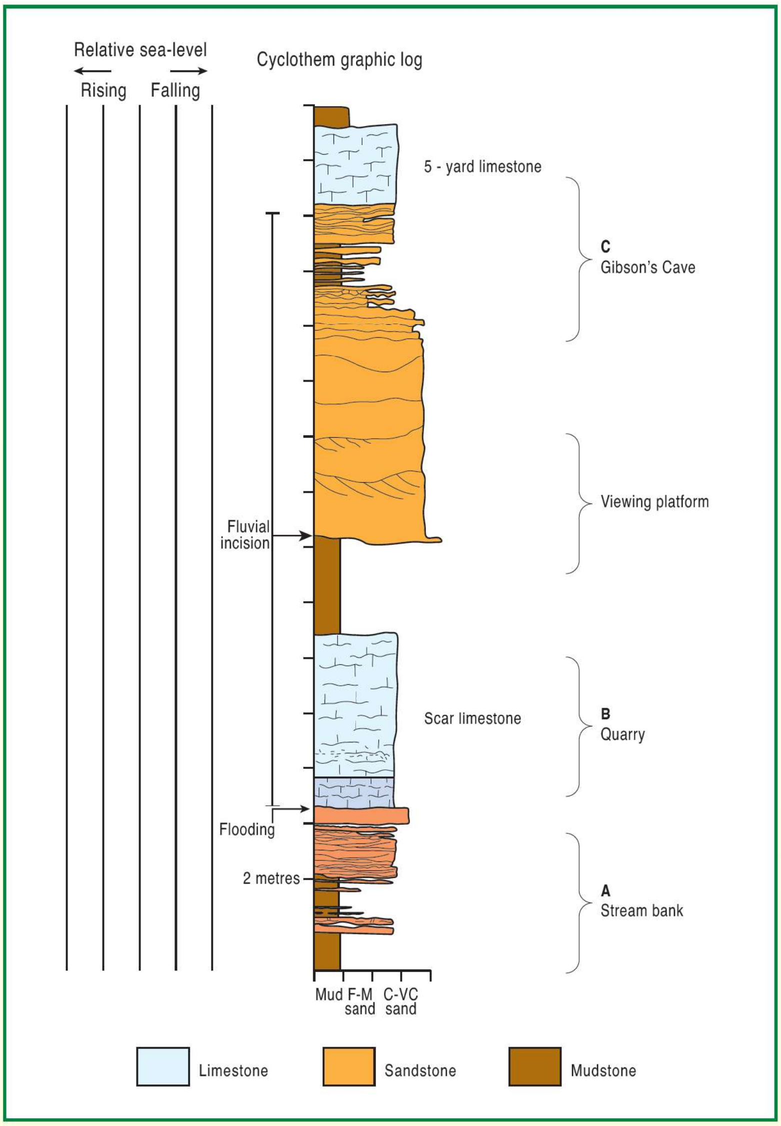
The different types of sedimentary rocks and how they were laid down was controlled by the ancient sea level during the Carboniferous period.

Draw a curve in the space provided on the graphic log sheet to represent the sea level during the carboniferous for the rocks seen at Bowlees at Stops A to C.



Limestones are usually deposited in a marine environment. What ancient environment do you think the sandstones and mudstones were deposited and why?

....

....

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Rock Tests

Rock Test 1 - What does the rock look like?

Use a hand lens to observe the rock carefully.

- What colour is it?
- Is it rough or smooth
- Is it shiny or dull?
- Can you see any crystals or grains?
- Are there any fossils?

2 - Is the rock hard?

Rock Test 2

Try to scratch the rock.

Rocks which can be scratched by a fingernail are called very soft.

Rocks which can be scratched by a copper coin are called soft.

Rocks which can be scratched by a nail are called hard.

Rocks which cannot be scratched by a nail are called very hard.

Rock test 3 - Does the rock soak up water?

Use a plastic pipette to drop a small quantity of water onto the rock sample.

What happens to the water?

Rocks that soak up water are called permeable

Rocks that do not soak up water are called impermeable

Rock test 4 - Does the rock react with dilute hydrochloric acid (Hcl)?

Use a plastic pipette to drop a small quantity of dilute HCl onto the rock sample

Does the rock react with the dilute HCl?

If the rock does react with dilute HCl, why do you think this happens?

This is a very reliable test to identify the sedimentary rock called Limestone

Other information

Make any additional comments about the different rocks you have collected. You could make comments about their colour and shape. Do they contain any fossils.

You will be able to recognise if some of the samples have grains that fit well together. They have an **interlocking texture**. But in some rocks the grains do not fit so well. We say that they have a **non-interlocking textur**e.

Rock Name

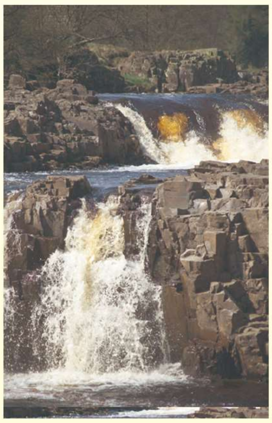
Attempt to name the rock samples you collected based upon the tests and you own observations. You could start by grouping the rocks into **igneous, metamorphic** or **sedimentary**.

You can also use the rock dial to assist in naming the different rocks.

ROCK DATA TABLE				
Sample Number	1	2	3	4
Rock test 1				
Rock test 2				
Rock test 3				
Rock test 4				
Other information				
Rock name				

STOP D Low Force (NY 904279)

Low Force is a small waterfall in the River Tees. Resistant outcrops of the Whin Sill form the waterfalls ('force' is from an old norse word for waterfall). Do not attempt to approach the waterfalls themselves. There is plenty of exposure away from the waterfall to see the rocks. Take care not to lose your footing on the wet and/or slimy rocks. Attempt the following questions:



Describe the rock that makes the Whin Sill (use your hand lens)

....

....

....

....

....

....

What rock type is the Whin Sill? Circle the correct answer

Igneous | **Metamorphic** | **Sedimentary**

What is the reason for your answer?

....

....

Now use the rock dial to name the rock:

....

If you have identified the rock that makes up the Whin Sill as Dolerite –well done! This is not an easy rock to recognise in the field and can easily be mistaken for basalt.

What is the difference between basalt and dolerite?

....

....

The Whin sill was intruded as a huge sheet into the surrounding sedimentary rocks.

As the dolerite intrusion cooled, the rock started to crack. These cracks are called **cooling joints** by geologists. The cracks occur due to contraction of the hot magma. The cooling of the magma usually produces vertical cooling joints in a polygonal pattern and these are called **columnar jointing.** Low Force (and High Force Stop G) offers you the opportunity to see inside a large igneous intrusion and identify columnar jointing.

Draw an example of polygonal columnar jointing? (make sure you include a scale)

Cross over the Wynch Bridge (NY 903280) – ONE AT A TIME

STOP E

After crossing over the bridge follow the path to the east walking along the bank of the River Tees. After 150 m you will see a large block of rock 2-2.5 m thick lying on top of the black Whin Sill.

Look very carefully at the contact between the Whin Sill and the rock overlying.

What is the nature of the contact? Circle the correct answer

Planar **Irregular** **Angular** **Rounded**

In this one exposure you can see igneous, metamorphic and sedimentary rocks. Look carefully at the rocks (using your hand lens) and answer the following questions:

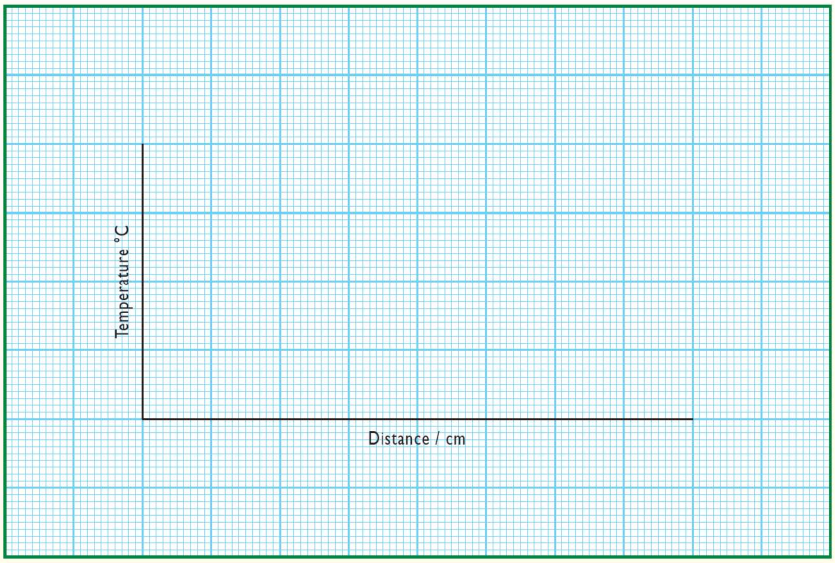
Match the names of the rocks with their types (use a line to join the correct answers)

Dolerite	Metamorphic
Baked Sandstone	Sedimentary
Sandstone	Igneous

By which process was heat transferred from the igneous intrusion into the sedimentary rock? Circle the correct answer

Radiation **Convection** **Conduction** **Evaporation**

The temperature of the Whin Sill at the time of intrusion may have been >1100 oC. However, this heat is quickly dissipated into the surrounding country rock.

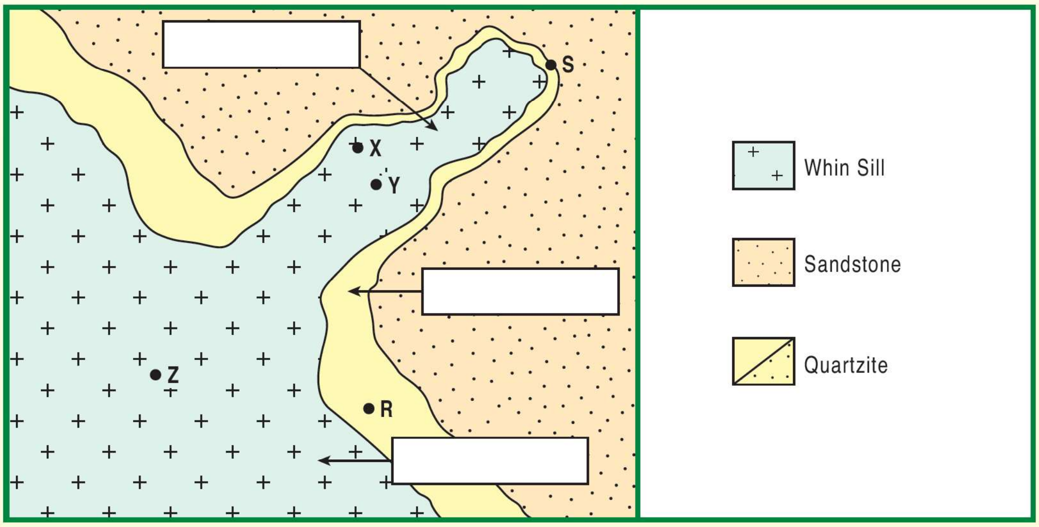


Sketch a curve to illustrate the fall in temperature with distance.

The diagram below shows the close relationship between the different rock types at this stop.

Carefully study the diagram and answer the following questions based on your detailed observations at this stop.

The rocks of the Whin Sill at points X, Y and Z contain crystals. The crystals formed more quickly in the Whin Sill at point X than the crystals at point Y and in turn the crystals at point Y formed more quickly than at point Z.



Where are the larger crystals found and why?.

....

....

What type of rock is formed around the outside of the Whin Sill at points R and S?

....

At points R and S the intrusion of the Whin Sill has altered the sandstone to form quartzite.

Why is the rock formed at point R thicker than at point S?

....

Complete the missing labels on the diagram above using the following geological terms

Baked Margin **Chilled Margin** **Contact**

If the Whin sill had intruded into a limestone how would the limestone have been altered and what is the name of the new rock?

....

....

....

....

Follow the route map along the banks of the River Tees to Holwick Heads Bridge – Stop G.

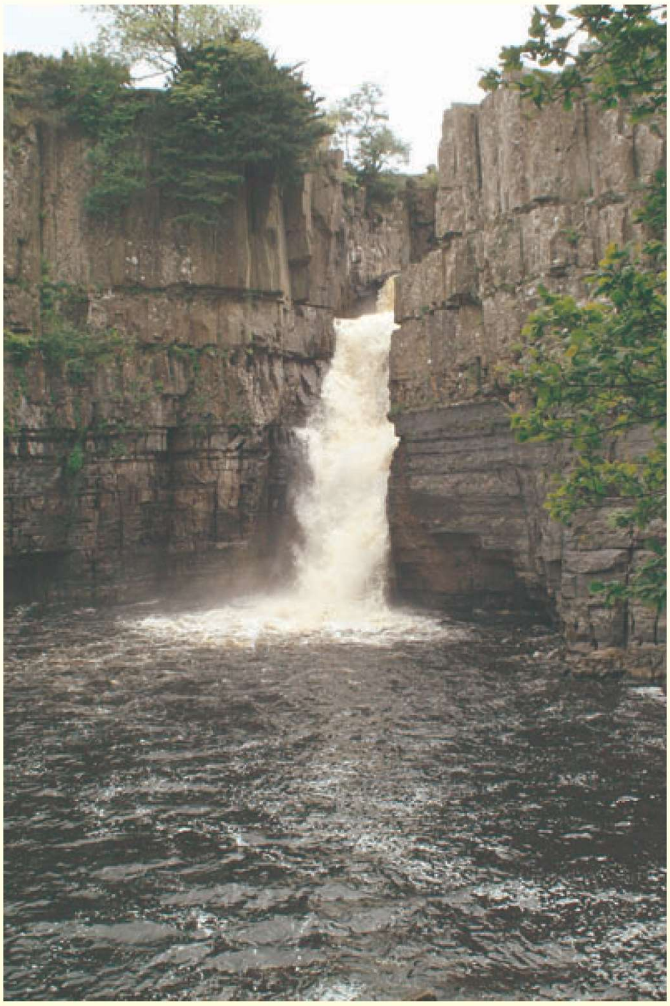
STOP F Holwick Head Bridge (NY 889283)

At this point the nature of the Tees valley changes where the river enters a deeply incised gorge and terminates with the waterfall of High Force. Near to the bridge the river crosses a major geological fault (a weakness in the Earth's crust) and its continuation marks the first part of the gorge.

Walk over the bridge and follow the path for High Force

STOP G High Force (NY 881284)

Label the photograph of High Force using the rock names of LIMESTONE, SANDSTONE and DOLERITE.



Facts about High Force:

The overall drop of the waterfall is 21m.

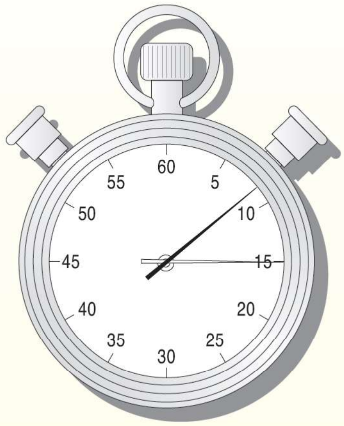
The gorge from high force down stream is approximately 700 m in length

The waterfall started to develop 11,500 yrs ago and the erosion is continuing today

The Whin Sill in comparison is 295 million years old

Quick Fire Quiz – Bowless, Low and High Force

Write the correct letter for each of the answers in the box.



1. Where are most fossils found?

a) Dolerite
b) Marble
c) Limestone
d) Granite
e) Basalt

☐

2. A limestone is

a) a metamorphic rock
b) an igneous rock
c) a sedimentary rock
d) a volcanic rock
e) a rock from the mantle

☐

3. What age are the rocks at Bowlees?

a) Triassic
b) Cretaceous
c) Carboniferous
d) Jurassic
e) Permian

☐

4. Typical fossils found at Bowlees are:

a) Crinoids, brachiopods and fosslised wood
b) Crinoids, fossilised wood and dinosaur bones
c) Fossilised wood, trilobites and corals
d) Corals, dinosaur bones and crinoids
e) Ammonites, bivalves and trilobites

☐

5. The Whin Sill is made of:

a) Granite
b) Sandstone
c) Mudstone
d) Basalt
e) Dolerite

☐

6. Where an igneous rock is found intruded into sedimentary rocks the margins of the igneous rock are:

a) Faulted
b) Folded
c) Baked

☐

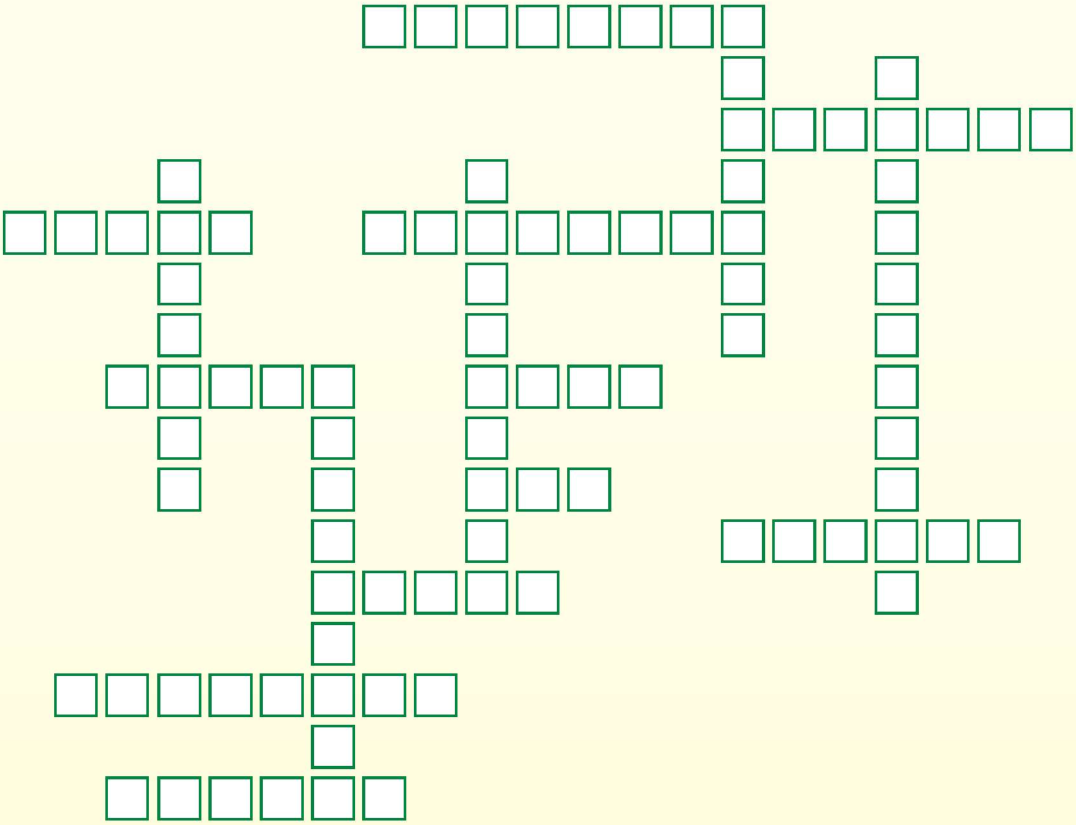
7) Due to the faster cooling of igneous intrusions at their margins do you think the crystal size will be:

a) Smaller than normal
b) Larger than normal
c) No difference

8) The main process of transferring heat from an igneous intrusion into the surrounding rocks is by:

a) Convection
b) Conduction
c) Radiation

Geology Puzzle



Baked
Crinoids
Fossils
Geology
Grains
Hammer
Hand lens
Igneous
Limestone
Map
Metapmorphic
Notebook
Rocks
Sandstone
Shale
Sill

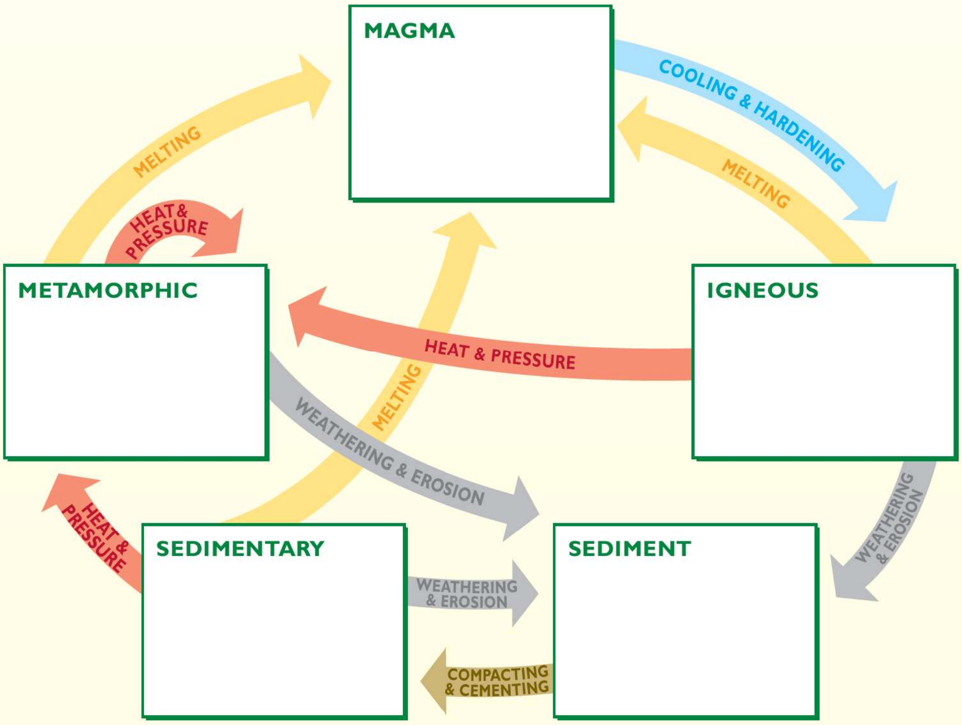
Low Force and High Force: Let's Rock!

Follow-up Activity 1

IGNEOUS, SEDIMENTARY AND METAMORPHIC ROCKS

The Rock Cycle – The rock in the Earth's crust is being continually destroyed and recycled. Rock on the surface is worn down to fragments and is eventually deposited to form new sedimentary rock. Rock underground is melted to form igneous rock or squashed and cooked to form metamorphic rock.

1. Use the diagram below to explain how igneous, sedimentary and metamorphic rocks are formed. Write your answers in the box below:



2. Make your own igneous, sedimentary and metamorphic rocks!

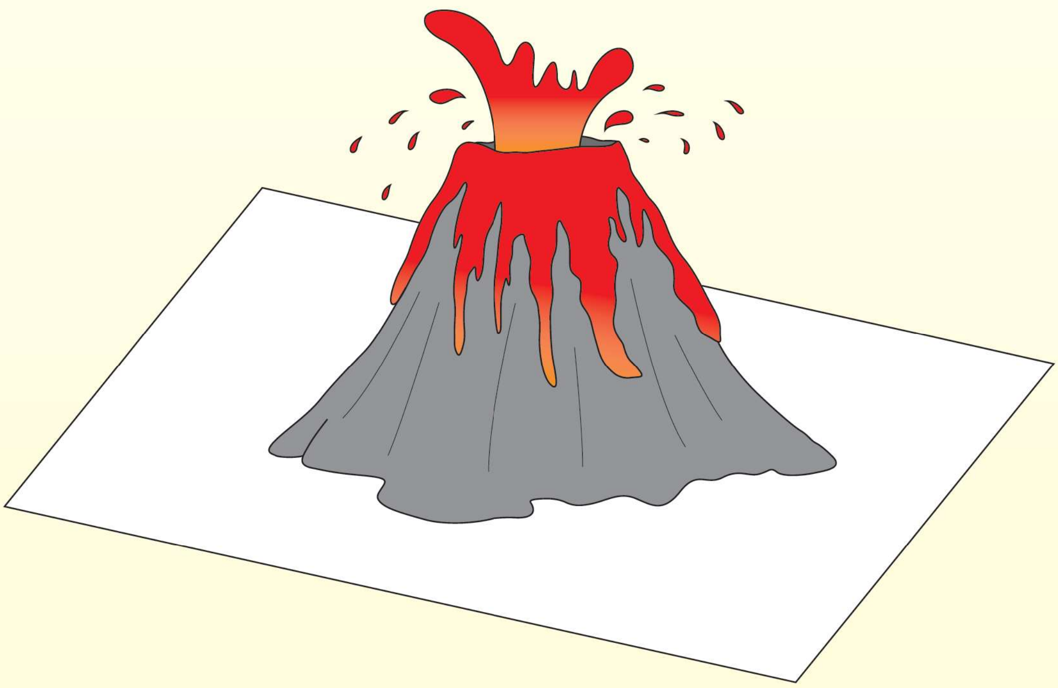
IGNEOUS ROCKS - MAKE A VOLCANO!

Materials

A jug	*Baking soda*	*Flour*
Stirring rod	*Funnel*	*Vinegar*
Red food colouring	*Tray*	*Sand*
Plastic bottle		

Instructions

1. Empty the baking soda and 3-4 spoons of flour into the jug. Mix with the stirrer.
2. Place the funnel into the neck of the plastic bottle. Pour the mixture of baking soda and flour into the bottle.
3. Put wet sand on the tray.
4. Stand the bottle with the baking soda and flour mix in the centre of the tray and pack the wet sand around it. Make the sand into a cone shape.
5. Pour the vinegar into the jug and add red food colouring to make it a rich red colour.
6. Place the funnel into the mouth of the plastic bottle and pour the vinegar into the bottle. Quickly remove the funnel from the bottle.
7. The sandy volcano you have made will begin to erupt. The vinegar and soda mix to give off carbon dioxide. This makes the flour turn frothy and forces it out of the bottle as red lava!



SEDIMENTARY ROCKS - MAKE YOUR OWN SEDIMENTARY ROCK!

Sedimentary rocks are made up of layers of different types of sediment as the sediment is deposited in the sea or lakes. The layers are called strata. In this activity you will make your own sedimentary rock with different strata.

Materials

A large jar	Spoon	Kidney beans	Rice	Modelling clay
Flour	Brown sugar		Lentils	

Instructions

1. Press one edge of a large jar into a piece of modelling clay, so that the jar sits at an angle. Carefully spoon a layer of flour about 2cm think into the jar.
2. Carefully add layers of kidney beans, brown sugar, lentils and then flour again, until they nearly reach the top of the jar.
3. Remove the jar from the clay and stand upright. The differently coloured layers are like a section through a sequence of natural sedimentary rocks.

MAKE FAKE SHELLY LIMESTONE!

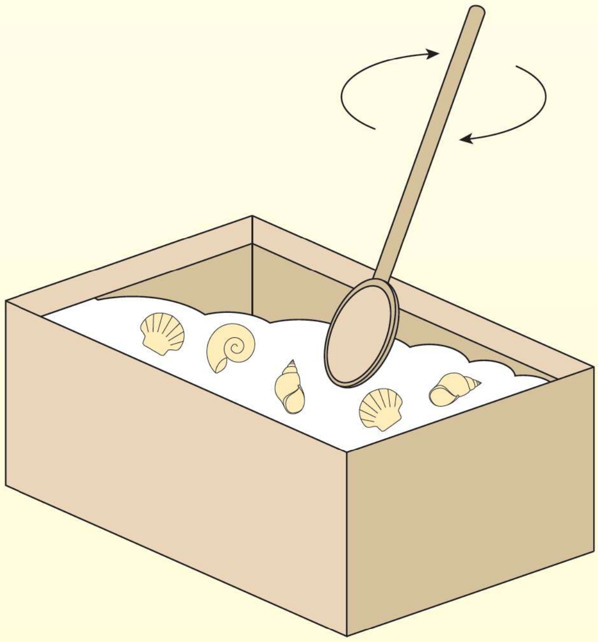
Limestone often contains fossils as it is formed in warm seas where the hard parts of marine animals are buried in the sedimen t when they die. If you split open shelly limestone you can find beautifully preserved seashells. See if you can make some convincing fake shelly limestone to fool your friends!

Materials

Seashells	Plastic container (or old shoe box)	Mallet or hammer
Cold black coffee or yellow food colouring (optional)		
Plaster of Paris	Plasticene	
Chisel	Old plastic bag	

Instructions

1. From your collection of seashells break some up into smaller pieces.
2. Make a rough 'rock-shaped' mould with the plasticene.
3. In the plastic container mix the plaster of Paris with water according to the instructions on the packet. Stir in your seashells. If you want to make a more sandy coloured limestone mix the plaster of Paris with cold black coffee or yellow food colouring instead of just water. You can also add some sand to make it feel gritty.
4. Pour the mixture into the plasticene mould, or use a plastic bag inside an old shoe box.
5. Let your plaster harden overnight. Ask an expert to identify your rock! Will you manage to fool them?
6. With care you can now use your mallet and chisel to discover the fossils in your rock



METAMORPHIC ROCKS - MAKE YOUR OWN FUDGE!

Metamorphic rocks have been changed by heat and pressure. You are now going to make sedimentary fudge and then turn it into metamorphic fudge!

Materials

300ml milk	100g butter
450g granulated sugar	2.5ml vanilla essence
Saucepan	Scales
Wooden spoon	Help from an adult

Instructions

To make sedimentary fudge:

1. Pour milk into a saucepan. Bring it slowly to the boil.
2. Add sugar and butter.
3. Heat slowly, stirring all the time, until the sugar dissolves and the butter melts.
4. Bring to the boil. Cover pan with lid. Boil for 2 minutes.
5. Uncover and continue to boil steadily, stirring occasionally, for a further 10-15 minutes or until a little of the mixture, dropped into a cup of cold water, forms a soft ball when rolled between finger and thumb.
6. Remove from heat. Stir in vanilla essence. Leave mixture to cool for 5 minutes.
7. Beat fudge until it just begins to loose its gloss and is thick and creamy.
8. Transfer to a 18cm square tin.
9. Mark into squares when cool and cut up when firm and set.

Taste the fudge and note down what it tastes like and its texture. Do not eat all the sedimentary fudge as you now need to change it by heating it again to make it a metamorphic fudge!

To make metamorphic fudge:

1. Heat the oven to 200 oC.
2. Place the spare sedimentary fudge into the oven.
3. Watch the sedimentary fudge heat and flow in the oven. Do not let it burn.
4. Take out of the oven when it is light brown on top. Care is needed as this will be a very hot liquid.
5. Allow to cool and then taste the metamorphic fudge to compare the taste and texture with the sedimentary fudge.

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CHEMICAL WEATHERING OF LIMESTONE: MY BREATH AND ROCK CHIPPINGS FROM THE CAR PARK

INTRODUCTION

Loose **limestone** (largely calcium carbonate) fragments are often used as the surface of drives and car parks as well as in making roads. In this activity you can discover how the limestone fragments found in your local area are attacked by the weather.

What you will need

- eye protection
- 250 cm^3 beaker
- drinking straw
- deionised / distilled water
- Universal Indicator solution in a dropping bottle
- white paper
- several limestone fragments

Safety notes

- Wear eye protection

What to do

Pour a 2 cm depth of distilled / deionised water into the beaker. Add enough drops of Universal Indicator to colour the water clearly. Stand the beaker of coloured water on white paper and carry out the numbered activities in Table 1. Write your answers in the spaces in the Table. You should make your predictions before trying any more experiments.

Low Force and High Force: Let's Rock!

Follow-up Activity 3

COOLING AND CRYSTAL SIZE

PURPOSE

To show the relationship between speed of cooling and crystal size.

Activity

Draw up a table like this with three empty lines.

Temperature of slides	Time of crystallisation	Number of centres	Size of crystals	Average size of crystals

1. Choose a pair of slides at room temperature.
2. Put one slide in the centre of the black piece of paper.
3. Use the glass rod to put a drop of salol on the slide and then immediately put the other slide on top and squeeze it down.
4. Label the slide with the temperature and your initials.
5. Start the timer as soon as the first crystals appear.
6. Make a diagram to show where the crystals start to grow.
7. Watch the process of crystallisation and draw several diagrams to illustrate the way the crystals grow and meet each other. Describe the process of crystallisation. Turn the timer off when crystallisation is complete.
8. Examine the slide and record the grain size of the ten largest crystals or all if less than ten.
9. Repeat with the other pairs of slides. Try to make the size of the drop of salol the same each time.
10. Plot the range of crystal sizes in each slide against temperature of the slide.

TEACHER SECTION

Requirements

Melted salol. (phenyl salicyclic) Do not over heat, Melt in a water bath at 60oC.

For each pair of students:

2 slides at room temperature

2 slides at 5°C (use a fridge) or 0°C (use ice)

2 slides at 30°C use an oven or the top of a radiator

The slides should be 5cm by 5cm glass slides. Alternatively use petri dishes or pieces of 2mm glass.

Timer

Glass rod

Pen for writing on glass

Hand lenses and grain size scale.

An A5 piece of black paper (makes the crystal growth easier to see)

Notes

This activity is best done if it is tied in with rock samples with different grain sizes for instance samples taken across a dyke.

Speed of crystallisation is dependent on the size of the drop of salol so as far as possible the drops should be the same size. It is also dependant on the initial temperature of the salol.

If the room temperature slides take a long time to crystallise then omit the warm slides. The salol on the cold slide may crystallise too quickly to be timed and with too fine a grain to be measured.

The glass slides can be reused if washed in hot water. It is useful to keep examples of slides which have crystallised well.

Time

30 minutes

Results

Crystallisation usually begins on the edges. The crystals grow as expanding circles until they touch each other. The cooler slides

crystallise more rapidly. The crystals are often finer at the edges.

Cost

Salol £12 for 250g

(2011 prices)

Low Force and High Force: Let's Rock!

Follow-up Activity 4

ROADSTONE

PURPOSE

To determine the best types of rock for making the wearing course for roads.

Background

Whereas most rock types can be used for the lower layers of a road, the rock used for the wearing course has to have very precise characteristics if it is to be used on important roads. It has to be hard so most minerals contained in the rock must have a hardness greater than 5. In order to remain rough and to provide a good grip for the tyres the rock must have two or more minerals of different hardness. The grain size of the minerals within the rock must be less than 2mm. The rock must be strong otherwise the pressure from the tyres would break it up. It must have low porosity otherwise water will get in and the frost will shatter it. Lastly tar must adhere well to it so glassy rocks like flint and obsidian will not do.

Activity

1 Set out a table like this with 12 lines

Rock	Grain size	Minerals with hardness of each

2 Identify the rocks and note their grain size, if too small to measure put <2mm

3 Identify or look up the mineral composition of each rock.

4 Look up or work out the hardness of each mineral.

5 Now use this data to fill in a table with this format with 12 lines. Put a tick if the rock has the characteristic.

Rock	Most minerals with hardness >5	2 or more minerals	Grain size <2mm	Strong rock	Tar adheres well	Low porosity

6 Identify the rocks which are suitable for wearing course roadstone

TEACHER SECTION

Requirements (see notes)

A variety of rock samples, about 12 is suitable. They should include dolerite, basalt and greywacke sandstone.

Samples of the minerals found in the rocks.

Mineral hardness testing set.

Notes

This is a good exercise for revision of rocks and minerals. It is simpler, but not such good revision, if the mineral composition of each rock is given and also the hardness of each mineral.

Results

Dolerite, basalt and greywacke sandstone satisfy all the criteria.

Time

60 minutes

ORGANISATIONAL DETAILS

Aim

1. To reinforce the rock cycle and how it can be applied in the field.
2 To identify sedimentary, igneous and metamorphic rocks in the field.
3. To identify the processes that happen to alter a sedimentary rock to a metamorphic rock
4. To link with localised mineral deposits and appreciate the importance of applied aspects of geology and understanding the landscape.

Target Group

Key Stage 3 geology, science and geography. However, the exercise could be easily adapted for Key Stage 4.

Location

This fieldwork is located at Moor House, Upper Teesdale National Nature Reserve, focusing on the walk alongside Cow Green Reservoir and Cauldron Snout.

Practical Details

The fieldwork starts from the car park next to Cow Green Reservoir and involves a walk of approximately 3km each way to complete all the stops (allow 3-4 hours). The walk will take in various geological stops and will culminate at Cauldron Snout waterfall. If travelling by coach it is advised that the coach drops off and collects from the car park at Cow Green.

Materials Required

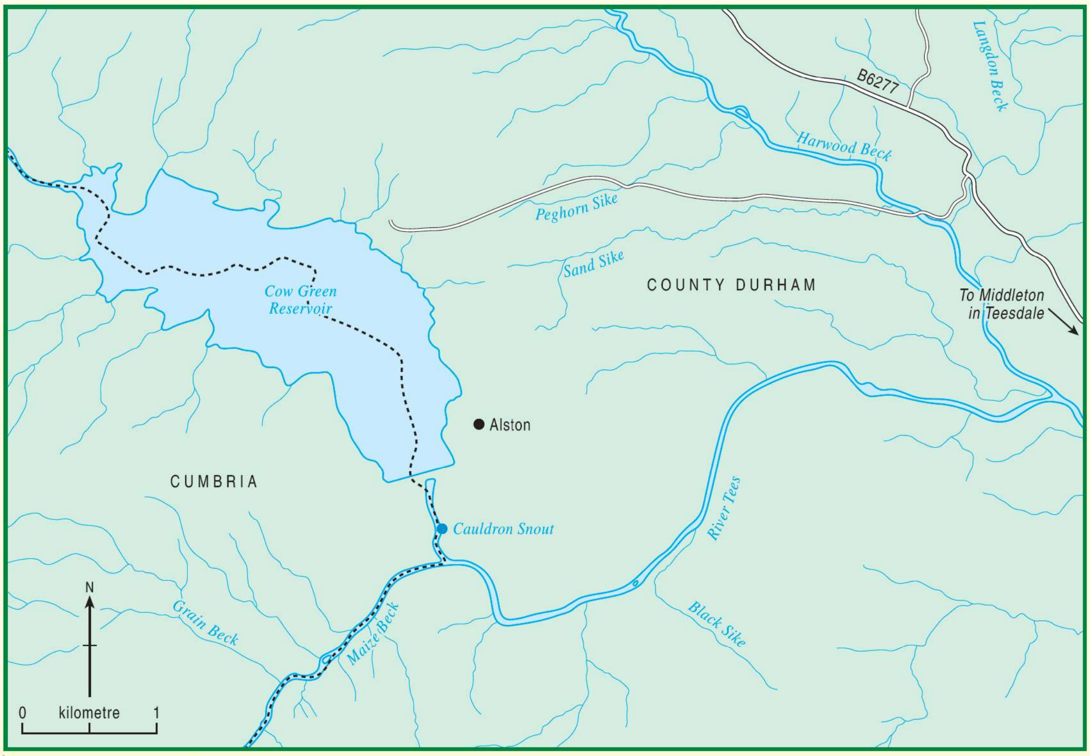
- Clipboard • Pencil
- Hand lenses - available through Rock Boxes
- Rock and mineral dials (optional)
- Grain size cards - available through Rock Boxes

Safety Issues

- Upper Teesdale can experience bad weather and like much of the North Pennines is an exposed area. Staff and students should be prepared for extreme weather conditions and all need to wear suitable warm clothing and footwear.
- In some places old mine workings are present that may be unstable. Do not attempt to enter any of these old workings and only keep to the designated paths.
- Refer to the Hazards Identification Sheet.

Cauldron Snout: Baked Rocks

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 by 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 be careful when crossing the road from the car park to the start of the walk to Cauldron Snout. All students and staff.	Supervise students while crossing 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.
Disused mine conditions	The route passes several old mine workings, parts of which may be unstable. All students and staff.	Warn about old mine workings and to keep to the designated paths at all times.
Walking down Cauldron Snout (optional)	The Whin Sill can be slippery when wet. Extreme caution is required as some of the route requires some scrambling over the rocks. All students and staff.	Supervise students at all times while making their way down the path at the edge of Cauldron Snout. If raining heavily or in extreme weather NOT to be attempted Keep together as a group.
Cow Green Reservoir and Dam	Cow Green Reservoir is very deep and the water is very cold even in summer. All students and staff.	Supervise all students and keep away from the edge of the reservoir, the dam and sluice gates.

Plan of activities

Follow map – 'Geological walk: Baked Rocks!'

Stop 1: Overview of the landscape at the car park viewing point. Look at the hills and flat areas and consider the underlying geology (~15 mins)

• Head to Stop 2.

Analysis of sedimentary rocks and observation of the landscape to determine differing weathering rates. (~ 20 mins)

• Follow the road using the map. The road crosses a small stream and as you reach the top of the next rise look on your left for a shallow linear trench. This is Rods mineral vein at Stop 3 where galena and baryte minerals can be examined and discussed (~20 mins)

• Continue to follow the road to Stop 4 'Sugar limestone'. Follow the activities using grain size cards and hand lens (30 mins)

• Continue on the road to Stop 5 at Red Sike. This the first stop where the Whin Sill can be observed. Offers the opportunity to identify the igneous rock as a heat source for the metamorphism of the Carboniferous limestone to marble as seen at Stop 4 (30 mins)

• The road will lead you past the Cow Green Dam where you should stop to look at the dam and appraise why geographically and geologically it was built in this location (Stop 6; 15 mins).

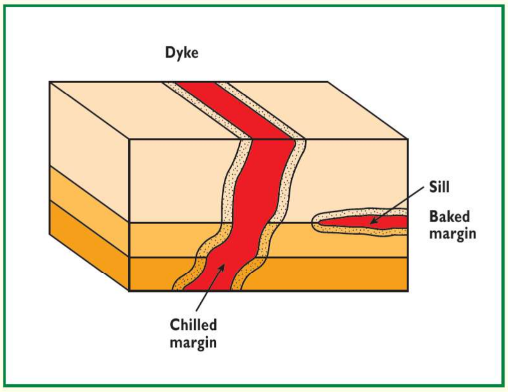
• Just before the bridge over the River Tees, turn off the road and onto the sign posted Pennine Way. Stop 7 is located at the top of the Couldron Snout waterfall and Stop 8 at the foot of the falls. Several observations are required here and can be followed up with a summary rock cycle exercise (~60-80 mins)

BACKGROUND INFORMATION

Cauldron Snout and Moor House, Upper Teesdale - Baked Rocks!

General Geology and Landscape

The Whin Sill is one of the most famous geological features of the North and due to its hardness and resistance to weathering it now stands out as cliffs and waterfalls in Teesdale (e.g. High Force and Cauldron Snout) and along the North Pennines escarpment in the Vale of Eden and Cumbria (e.g. High Cup Nick). The Whin Sill is a tabular layer of igneous rock that formed 295 million years ago when magma rose from deep within the Earth at temperatures >1100°c. The magma did not erupt at the surface but was instead forced (intruded) between the layers of Carboniferous sediments.



As the magma cooled it solidified into sheets known as sills, that can reach up to 70 m thick, and formed a hard black/dark grey, crystalline rock called a dolerite. Dolerites are an example of an intrusive medium-grained igneous rock, mineralogically the same composition as basalt with the minerals pyroxene and feldspar. As the magma cooled it started to contract and vertical cracks developed that are roughly shaped as columns known as columnar joining. The columnar joining is particularly apparent at Cauldron Snout.

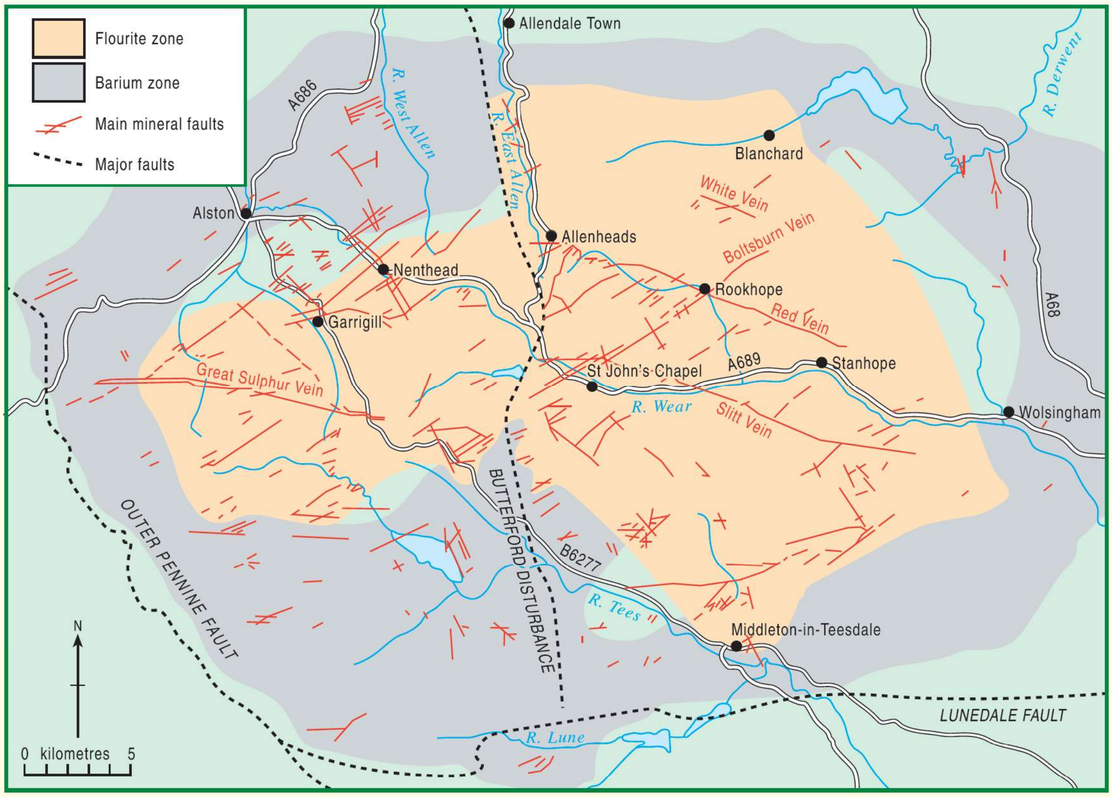
The geology of Cauldron Snout and Moor House, Upper Teesdale National Nature Reserve provides one of the best examples of metamorphism (alteration) within the North Pennines Geopark. The intrusion of the igneous Whin Sill in to the Carboniferous sediments caused the sediments to be baked and altered, a process known as contact metamorphism. This processes is particularly apparent in Upper Teesdale where limestone turned into a distinctive white crystalline marble, known as 'Sugar Limestone'.

The resultant sugar-like marble is highly rich in lime, enabling many calcicolous species to thrive. The high rainfall and low annual temperatures encountered in this area strongly resembles the severe conditions experienced on the Scottish mountains and the European Alps. These climatic conditions and the surface exposures of a unique form of Carboniferous limestone combine to produce an unusual type of grassland community which occurs extensively on Widdybank Fell and Cronkley Fell high in Upper Teesdale NNR. The sugar limestone grassland is enriched by a number of plants usually found in Arctic and Alpine places, and which are able to tolerate the harsh climate.

Figure 1. The sugar limestone supports a remarkable range of plants and the associated wetlands and harsh Alpine climate. a) Spring gentian (Gentiana verna). This its only habitat in mainland Britain. b) Near to wet pools and boggy areas close to the Whin Sill and Cauldron Snout round leaved Sundew grows. These produce a sticky substance on their leaves that traps insects.

To add further complications to the geology encountered at Cauldron Snout the rocks have been mineralised with l ead (galena) and barium (baryte) minerals concentrated along mineral veins. Veins are sheet-like bodies of mineral that occupy more or less vertical cracks or fissures in the rocks. The hundreds of veins known in the North Pennines form a distinctive pattern that tend to follow faults, cracks in the Earth where rocks on either side of the fissure have moved due to millions of years of Earth movements. Many of the veins were found by local miners during the 1800's and named due to their appearance (e.g. Red Vein, White Vein). The veins of lead and barium ore formed about 290 million years ago when hot mineral-rich waters flowed through cracks and fissures deep underground related to the emplacement of the Whin Sill. As the fluids cooled, the dissolved minerals crystallized within the cracks and gradually mineral veins began to form.

Cauldron Snout provides one of the most compact and easily accessible locations for students to investigate the rock cycle with many opportunities to see close up igneous, metamorphic and sedimentary rock types.



Map of mineral veins as from Allenheads and Westgate activities.

Cauldron Snout: Baked Rocks

Student Information Sheet 1

BAKED ROCKS!

Cauldron Snout: Baked Rocks

Student Resource Sheet 1

BAKED ROCKS!

Aims of exercise:

1) To analyse different rock types in the field and understand how they formed;
2) To recognise the effects of an igneous intrusion (Whin Sill) on sedimentary rocks

What you need: a pencil, a hand lens and about 2-3 hours of time

Where you go: Follow the map on this handout and answer the questions with each of the geological stops (1 to 8).

STOP 1 Viewpoint Cow Green car park

Look to the west and you will see a distinctive array of hills known as Great and little Dun Fell and Cross Fell. Dun Fell would be just another Pennine summit were it not for the construction of a radar station on the summit. This plays a key part of the Air Traffic Control system for the North Atlantic area.

Why do you think the hills have flat tops?

....

....

Using the map follow the road to Stop 2

STOP 2 Grey Rocks

Along the road and path side you will see conspicuous areas of flat grey rock. These rocks are about 330 million years old and formed during the Carboniferous period. At this time the area of the North Pennines lay more or less at the equator with large shallow tropical seas.

There are three types of rock – igneous, metamorphic and sedimentary. Igneous rocks include granite and basalt. Metamorphic rocks include slate and marble. Sedimentary rocks include sandstones and limestones.

Look carefully at the grey rocks. Using your hand lens and rock dial see if you can identify the rock type.

....

Describe the texture of the rock and whether it contains any fossils.

....

....

Now follow the road to Stop 3

STOP 3 Mineral vein

Most rocks are mixtures of minerals that can be found in many different shapes and sizes. Sometimes due to geological processes, minerals become concentrated in more or less vertical fissures and cracks in the Earth's crust, –these are called **mineral veins**.

This mineral vein was mined by miners in the 1800's and you can still see a shallow trench that marks the line of the mineral vein. The old spoil heaps next to the mineral vein still contain some of the minerals extracted by the miners.

Carefully look for different minerals on the spoil heaps.

Use the mineral dial and your hand lens to identifying some of their distinguishing properties. Complete the table below (one common mineral has already been identified to help you):

Mineral name	Colour	Hardness	Shape of crystals	Chemical formula
Quartz	White to colourless	Very hard - harder than steel		SiO_2

The minerals mined here and across much of the North Pennines had an important economic value, but the mineral veins have now been exhausted. What do you think the minerals you have found were once used for?

....

Using the map follow the road until you reach Stop 4

STOP 4 'Sugar limestone'

The small rocky outcrops either side of the road, are of the rock type called sugar limestone. The name will make you think that this rock type is sedimentary.

Look carefully at the sugar limestone using your hand lens.

Carry out some simple tests on the sugar limestone and write your answers in the rock table (this will also be used for stop 5).

Rock Tests	**Sugar limestone** (Stop 4)	**Whinstone** (Stop 5)
What colour is the rock?		
Is it rough or smooth?		
Is it shiny or dull?		
Can you see any crystals or grains?		
Is the rock hard or soft?		
Does the rock break easily?		
Are there any fossils?		
What rock type is it? *(Igneous, metamorphic or sedimentary)*		

Now move onto Stop 5 at Red Sike.

STOP 5 Red Sike

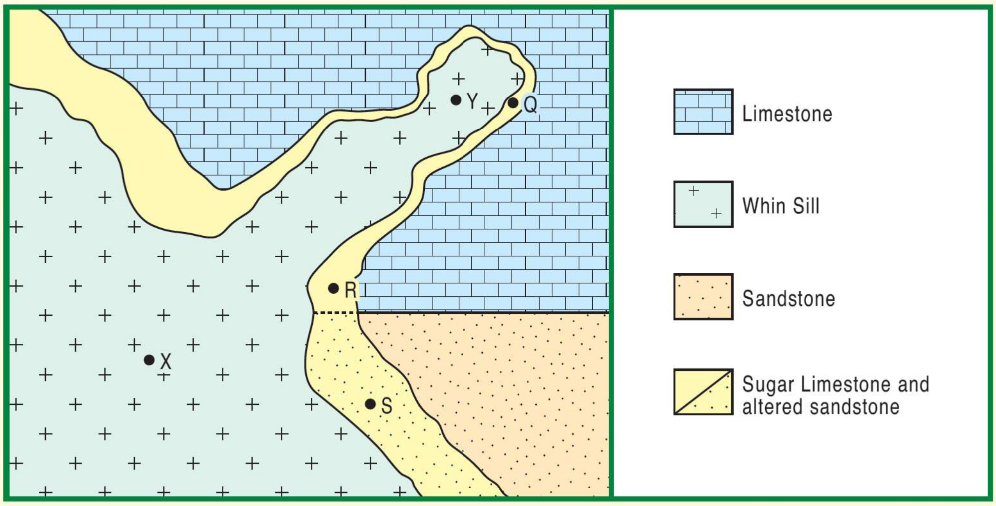
The rusty brown rocks that are found in the stream are part of the Whin Sill. They are rusty brown because of the river flowing over them. Look around Stop 5 for some fresh rock samples.

Look carefully at the Whin Sill using your hand lens.

Carry out some simple tests as used at Stop 4 and complete the Rock Table.

The diagram below shows the close relationship between the different rock types at stops 4 and 5.

Carefully study the diagram and answer the following questions based on your detailed observations at Stops and 5.



The Whin sill is made of a rock called dolerite that formed 295 million years ago. The dolerite was injected into the limestones and other rocks as a hot liquid at over 1100°c.

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What rock type is dolerite? Tick the correct box.

Metamorphic ☐ Igneous ☐ Sedimentary ☐

The rocks of the Whin sill at points X and Y contain crystals. The crystals formed more quickly in the Whin Sill at Y that the crystals at X.

Where are the larger crystals found and why?

....

....

What type of rock is formed around the outside of the Whin Sill at points Q, R and S?

....

At points Q and R the intrusion of the Whin Sill into limestone has altered the sedimentary rock to form Sugar Limestone. What is the more common name for the new rock created by the metamorphism of a limestone? Tick the correct box.

Basalt ☐ Slate ☐ Marble ☐

Why is the rock formed at point R thicker than at point Q?

....

Name the metamorphic rock at point S formed by altering sandstone.

....

In which of the rock types are fossils most likely to be found? Explain your answer.

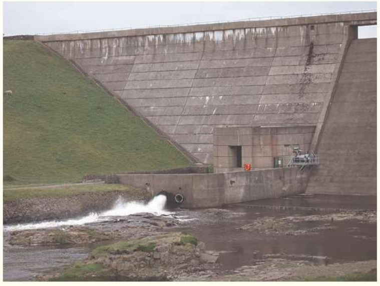
....

....

....

STOP 6 The Dam

The Cow Green dam was built between 1967 and 1971 to supply water to the industries of Teesside. Environmentally this part of Upper Teesdale is of national importance, and the plan to construct this reservoir was strongly opposed by local conservationists. However, the reservoir has provided many new habitats for wildlife and plants.



At the time of planning the reservoir, geologists were consulted on where the best position would be to build a dam with the minimum of environmental impact to the surrounding area.

Why is the dam built here? Do you think it may have anything to do with the underlying geology?

....

....

....

....

....

Just before the bridge over the River Tees, turn off the road and follow the path signposted Pennine Way. This will lead you to Stop 7 at the top of Cauldron Snout.

STOP 7 Top of Cauldron Snout

The rocks that make up Cauldron Snout are part of the Whin Sill and are called dolerite (same as stop 5). The Whin sill was intruded as a huge sheet into the surrounding sedimentary rocks.

As the dolerite intrusion cooled, the rock started to crack. These cracks are called **cooling joints** by geologists. The cracks occur due to contraction of the hot magma. The cooling of the magma usually produces vertical cooling joints in a polygonal pattern and these are called columnar jointing. Cauldron snout offers you the opportunity to see inside a large igneous intrusion and identify **columnar jointing**.

Make sure you have looked closely at the dolerite rock that makes up the Whin Sill.

Draw an example of polygonal columnar jointing in the box over the page?
(make sure you include a scale)

Follow the very steep steps down the side of Cauldron Snout, taking extreme care on the rocks. The rocks can be very slippery. If you are unsure about descending the steps you can still answer the questions to Stop 8 by looking around Stop 7 for similar features.

Do not attempt to descend the steps in bad weather or after heavy rain as the water level can rise very quickly.

STOP 8 Inside the Whin Sill

At the foot of Cauldron Snout looking back up, the waterfall gives you an impression as to it's size and the thickness of the Whin Sill. The waterfall from the top to the bottom is approximately 50 m and one of the highest in England. The Whin Sill is a little thicker at 75m.

At the foot of Cauldron snout you can clearly see the columnar jointing in the Whin Sill. Do not get confused by the differing colours in the dolerite igneous rock as it can often look black or very dark grey when wet.

The dolerite igneous rock that makes up the Whin Sill is quarried locally and used for road stone – Why?

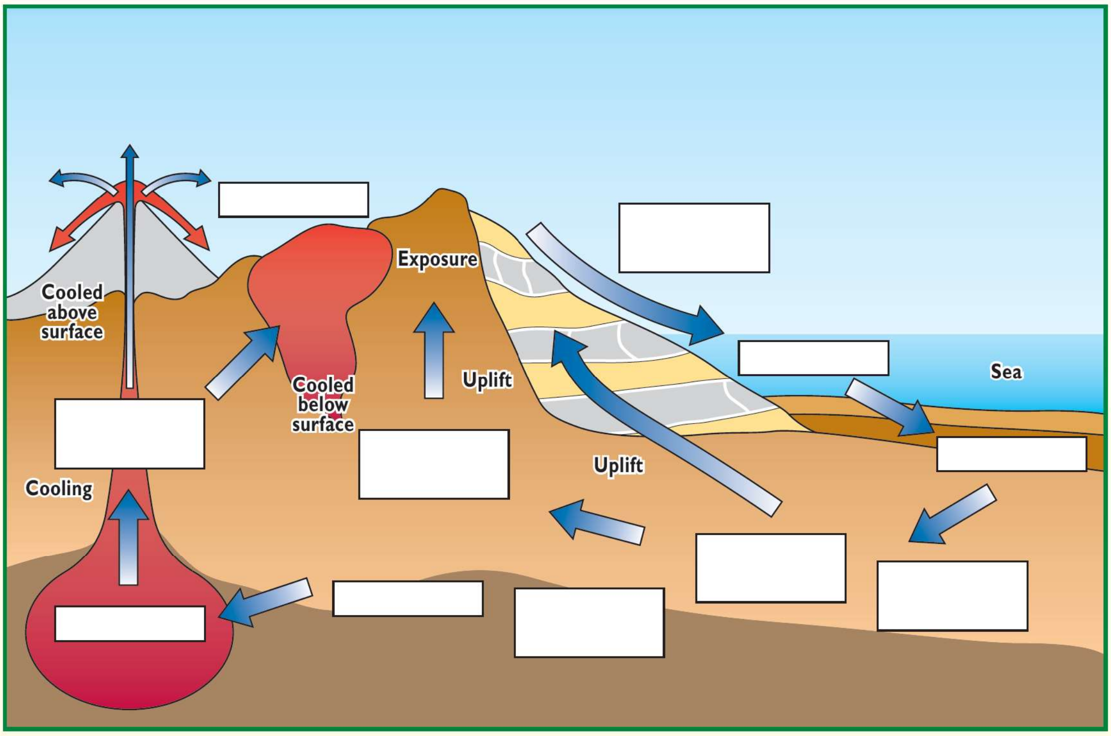
....

Summary Exercise

Now you have completed all the stops of the geological exercise at Cauldron Snout you should be familiar with the different rock types and processes that create such rocks.

Look at the rock cycle below.

Complete the rock cycle picture by filling in the missing words as listed below.



Igneous rocks **Sediments** **Magma** **Weathering & erosion**

Metamorphic rocks **Lava** **Sedimentary rocks** **Deposition**

Heat & pressure **Melting**

Cauldron Snout: Baked Rocks

Follow-up Activity 1

METAMORPHIC ROCKS: ANDALUSITE SLATE

Purpose

To see if there is any preferred orientation to andalusite crystals in andalusite slate. This can be undertaken on a sample of the Skiddaw Slates from the rock box that has suitably sized crystals

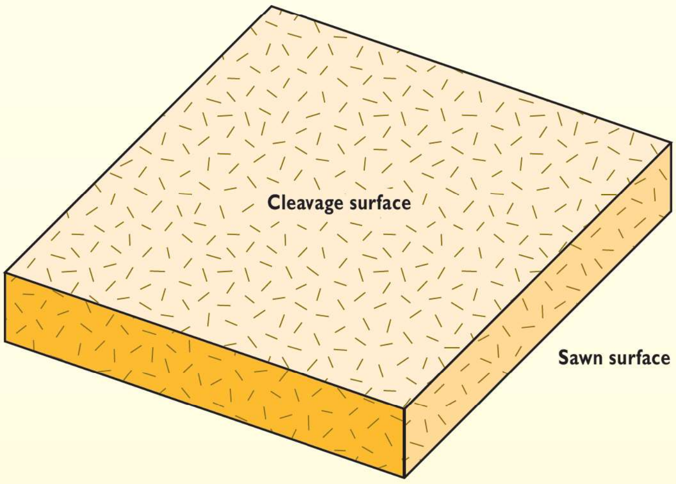
Activity

1. On the photocopy of the cleavage surface measure the angle of the crystals to the marked line. Use the protractor with the curved side on the right so that you only record angles between 0o and 180°. Make at least 20 measurements and number each crystal as you measure it.

2. Now record the angle of crystals exposed on one of the edges in a vertical plane. Hold the protractor with the 0° –180° line parallel to the cleavage and record the angle of as many crystals as you can.

3. Repeat activity 3 on the edge at right angles to the last one.

4. Plot as three separate rose diagrams.



Slab of andalusite slate cut at right angles to cleavage surface. The faces are then photocopied.

TEACHER SECTION

Requirements

Photocopies of a piece of andalusite slate, about 10cm by 30cm by 30cm with a line drawn on the cleavage face. Two edges should be cut at right angles and these also photocopied.

Protractors

Blank rose diagrams.

Notes

A sample of andalusite slate is found in the rock boxes and represents some of the oldest rocks found in the Geopark.

Checks

Make sure the students keep the protractor parallel with the line or the cleavage.

Results

There should be no preferred orientation.

Time

30 minutes for making the three sets of readings.

Cauldron Snout: Baked Rocks

Follow-up exercise 2

METAMORPHIC AUROLE

Purpose

To show how the temperature changes in the rocks adjacent to an intrusion as the intrusion cools. Thius would have been the case with the intrusion of the Weardale Granite. In the rock box there are several metamorphic rocks that should be looked at first and described along with the Weardale granite.

Activity

The sand represents the country rock and the hot water the intrusion.

1 Place four thermometers in the sand as shown in the diagram. Each thermometer should be placed so that the bulb is about 5cm below the surface.

2 Make up a chart like this but with at least 30 lines, to record the temperature shown by each thermometer.

Time	Temperature of water	Temperature of sand			
		1	1	1	1

3 Record the temperature shown by all the thermometers before pouring in the water.

4 Pour boiling water into the small tin and quickly put on the lid.

Place the fifth thermometer in the hole in the tin lid so that the bulb is 5cm below the lid.

5 Start your timer and start recording the temperature shown by each thermometer every two minutes until all thermometers show a decrease in temperature.

6 Plot all the temperatures on a single piece of graph paper. Use the graph paper in landscape format and plot temperature on the vertical axis 1cm = 5 degrees and time 1cm = 4 minutes on the horizontal axis.

7 Collect the data of tin diameter the inner tin, damp or dry sand, and time to maximum temperature for each thermometer from other students in a table like the one below.

Time to maximum temperature										
Name	Diameter	Dry or damp	Thermometer							
			1		2		3		4	
			Time	Temp.	Time	Temp.	Time	Temp.	Time	Temp.

8 For tins with dry sand plot size of the inner tin against time to maximum temperature. For two tins equal diameter but one with damp sand and one with dry sand plot the time to maximum temperature.

9 Answer the questions below.

a) How does the temperature change with distance away from the intrusion?

b) How does the size of the intrusion affect the size of the metamorphic aureole?

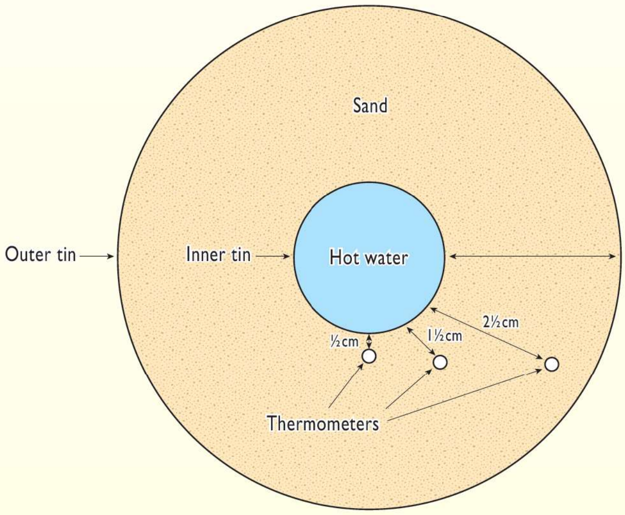
c) How does the size of the intrusion affect the thermal gradient?

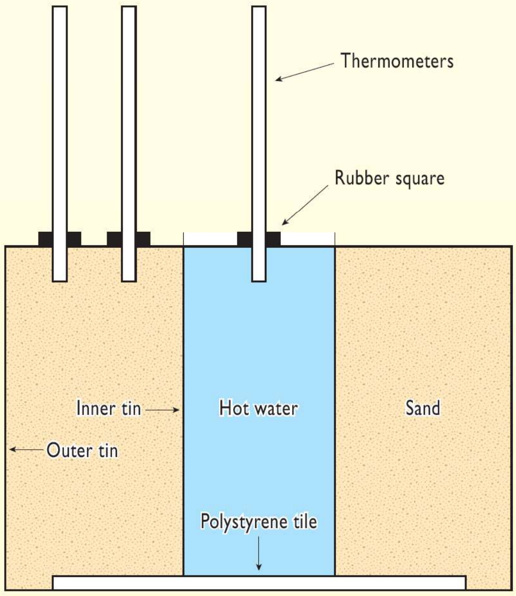
d) How does the temperature at any one place change with time?

e) Which will cool fastest a large or a small intrusion?

f) Does damp rock transmit heat energy more of less quickly than dry rock?

Plan view





Side view

TEACHER SECTION

Requirements

Round tins about 24cm diameter and 11 cm deep, Roses Chocolates tins are ideal. Alternatively a cake tin can be bought from a hardware store.

A variety of smaller tins about the same height but varying in diameter from 78 to 110 mm (see notes).

Sand

5 thermometers

Polystyrene tiles at least 25cm across

Timer

Kettles to boil enough water

Making the apparatus (About 1 hour for 5 tins)

Cut the tile to the size of the large tin and place it in the bottom. Place the smaller tin in the centre on top of the tile and fill the space between them with well compacted dry or damp sand. The thermometers should have small pieces of rubber or plastic collars on them to show what depth they should be inserted into the sand or water. Make a hole just large enough to take a thermometer in the centre of the lid of the smaller tin.

Notes

To show the variation of temperature away from an intrusion and with time you need only one outer and one inner tin but having the results from a variety of sizes of inner tins allows students to answer more questions. Smaller tins than those suggested could be used and would reach maximum temperature more quickly

Results

The sand farthest away takes longer to reach maximum temperature. The maximum temperature reached decreases away from the inner tin.

The innermost thermometer shows a very rapid rise in temperature and a slow decline. Other thermometers show a gentler rise in temperature.

The larger the inner tin the longer the cooling takes. Wet sand cools faster than dry sand.

Time

Readings need to be taken until all the thermometers begin to show a decrease in temperature. All the thermometers in a damp 78mm tin will cool with an hour. A 90mm diameter tin will take 100minutes but the change in temperature is very slow below 60°.