Fieldwork on The Pennine Escarpment

- **Science and geology**
  Dufton and Knock: Ancient rivers and even older volcanoes
  Appleby: Hot arid deserts
  Armathwaite: Hot and even hotter
  Brough: Tropical sea, fossils and climate change

- **Geo-activity Trail**
  Tynehead Geo-activity Trail

- **Signposting of places of interest and information on the Pennine Escarpment**

Science and Geology

ORGANISATIONAL DETAILS

Aim of fieldwork

To demonstrate how Earth science (geology) principles can be illustratred out of doors, in a simple and safe way. It can be used to engage pupils in discussions about Earth processes and science.

Target Group

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

Location

Dufton village centre car park; small craggy exposures of St Bees sandstone behind Dufton YHA along Wood Lane and Knock Pike.

Practical Details

This fieldwork is based around the village of Dufton and Knock Pike forming part of the North Pennine escarpment. It will start from Dufton village car park with the first stop examining the red sandstone blocks that make up the public toilets (Stop 1). Walk into Dufton village centre and past the YHA. A short distance past the YHA you will see a sign for 'Wood Lane to Brampton'. Take this track and walk past the garages and down a tree-lined path for about 50m. Along the side of this path are small exposures of St Bees red sandstone (Stop 2). Walk back to the car park and drive to Knock village. Follow the map and take the road leading to the Christian centre. Drive past the centre until you reach the end of the road. The last mile of this is unsuitable for coaches. Parking can be difficult. Stop 3 is Knock Pike which is located to the west of the road and can be reached by following the path in an easterly direction for ~30m. You will see that part of Knock Pike has been quarried away and provides excellent exposure and detail of the Ordovician volcanic rocks.

Materials Required

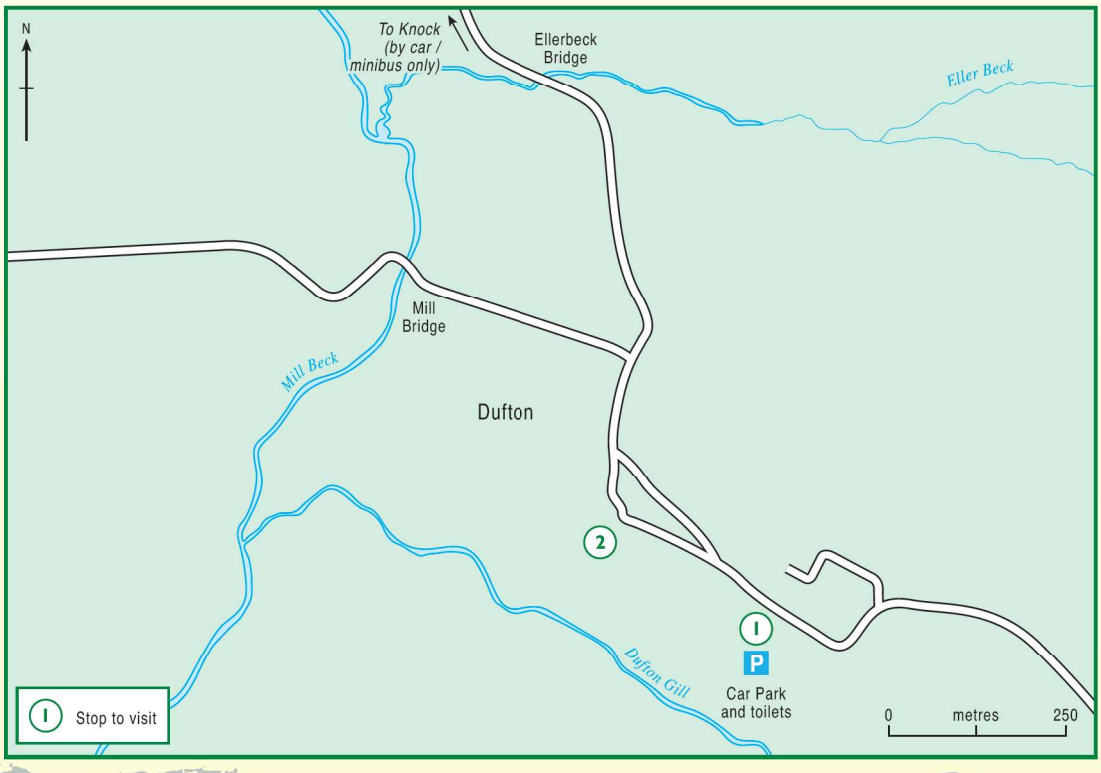
- Clipboard
- Pencil
- Copies of the student guide and worksheet
- Hand lenses - available through the Rock boxes
- Grain size cards - available through the Rock boxes

Safety Issues

- This region of the Vale of Eden and along the North Pennines escarpment can experience bad weather and like much of the North Pennines is an exposed area. Staff and students should be prepared for all weather conditions and all need to wear suitable warm clothing and footwear.
- Refer to the Hazard Identification Sheet

Dufton and Knock: Ancient Rivers and even older Volcanoes

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	Students need to take care when getting off the mini-bus or coach whether in a car park or at the road side as other vehicles may be passing. All students and staff.	Supervise students getting off the coach or minibus and gather in a safe place.
Uneven paths	Paths are uneven and may be slippery in wet weather. Students may slip and fall. All students and staff.	Warn about conditions..
Knock Pike Quarry	Steep-sided rock faces in quarry. Loose scree and steep grassy slopes. All students and staff.	Supervise all students and keep away from steep cliff faces. Hard hats are advised. Do not attempt to climb loose scree slopes or grassy banks.

Plan of activities

- Dufton car park - Look at the red Penrith Sandstone blocks that make up the building housing the public toilets Stop 1 (~20 mins)
- Walk into the centre of Dufton observing other buildings and houses made of red Penrith Sandstone. Folow signs for the Dufton YHA opposite the village green. A short distance past the YHA you will see a sign for 'Wood Lane to Brampton'. Take this track and walk past the garages and down a tree lined path for about 50 m. Along the side of this path are small exposures of St Bees red sandstone - Stop 2. Observe the rocks and make suitable notes. Compare and contrast the two red sandstones (40-50 mins)
- Stop 3 is Knock Pike located to the north of Knock village. You will see that part of Knock Pike has been quarried away and provides excellent exposure and detail of the Ordovician age volcanic rocks. Undertake detailed observations of the volcanic rocks and answer the related questions in the field (~90-120 mins).

BACKGROUND INFORMATION

From the Vale of Eden and northwards along the Pennine Fault escarpment red sandstones are used as a common building stone in many of the villages. The sandstones formed some 260 million years ago when the area was part of a large arid desert. The clues to unravel the history of these red sandstones can be found in natural rock outcrops and even the building stones used for many houses in the Vale of Eden.

Cumbria lay in a region of hot deserts from 270 to 220 million years positioned just to the north of the Equator, in a similar position as the Sahara desert today. These time periods are known to geologists as the Permian and Triassic Periods. To the west of the Eden Valley were the mountains, which today form the Lake District, while to the east and south were ranges of rocky hills – forerunners of the North Pennines. During the 200 million years since deserts covered the Eden and Cumbria areas, erosion has removed much of the evidence but sufficient still remains to allow the geological history to be reconstructed.

The oldest and most widespread of the rocks are the Penrith Sandstones of Permian age. Detailed observations of the Penrith Sandstone reveal clues about its desert dune origin. The very well rounded grains of sand (quartz) are characteristic of wind-blown sand from relentless movement and sand blasting. The red staining that coats the grains of sand is a mineral called haematite (iron oxide) and shows that the environment must have been oxidizing (shortly after if not actually during deposition). This red colour typifies continental fluvial and desert dune sediments. The Penrith sandstone has been used to build the toilet block and bus shelter in the main Dufton car park.

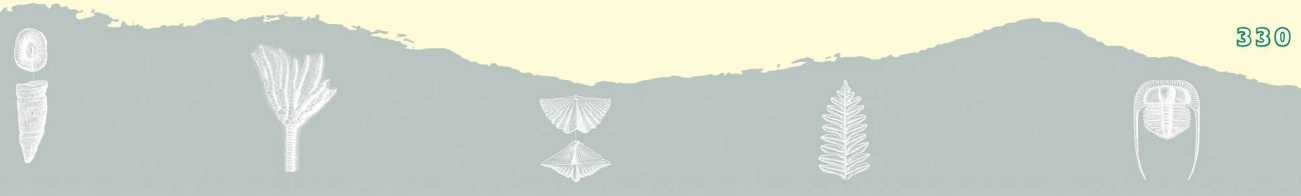
During the Triassic the climate became more humid and flash floods and seasonal rivers evolved across the desert plains. This climate is characterized by the St Bees Sandstone. The St Bees Sandtsone is very similar to the Penrtith Sandstone on intial observation but when inspected more closely it often contains mud flakes and the grains are less well rounded. The St Bees Sandstone can be inspected in Dufton at the Wood Lane exposures.

The oldest Rocks in the North Pennines

The oldest rocks in the North Pennines are found along the faulted Pennine escarpment. They underlie most of the North Pennines and are mostly slates, shales and volcanic rocks that formed between 500 and 420 million years ago in the periods on Earth known to geologists as the Ordovician and Silurian. These rocks were deposited at the edge of a wide ocean known as Iapetus Ocean. The ocean has been dated to close at round 420 million years ago when northern England, then part of the northern edge of a continental plate, collided with another huge continent which contained Scotland and much of North America.

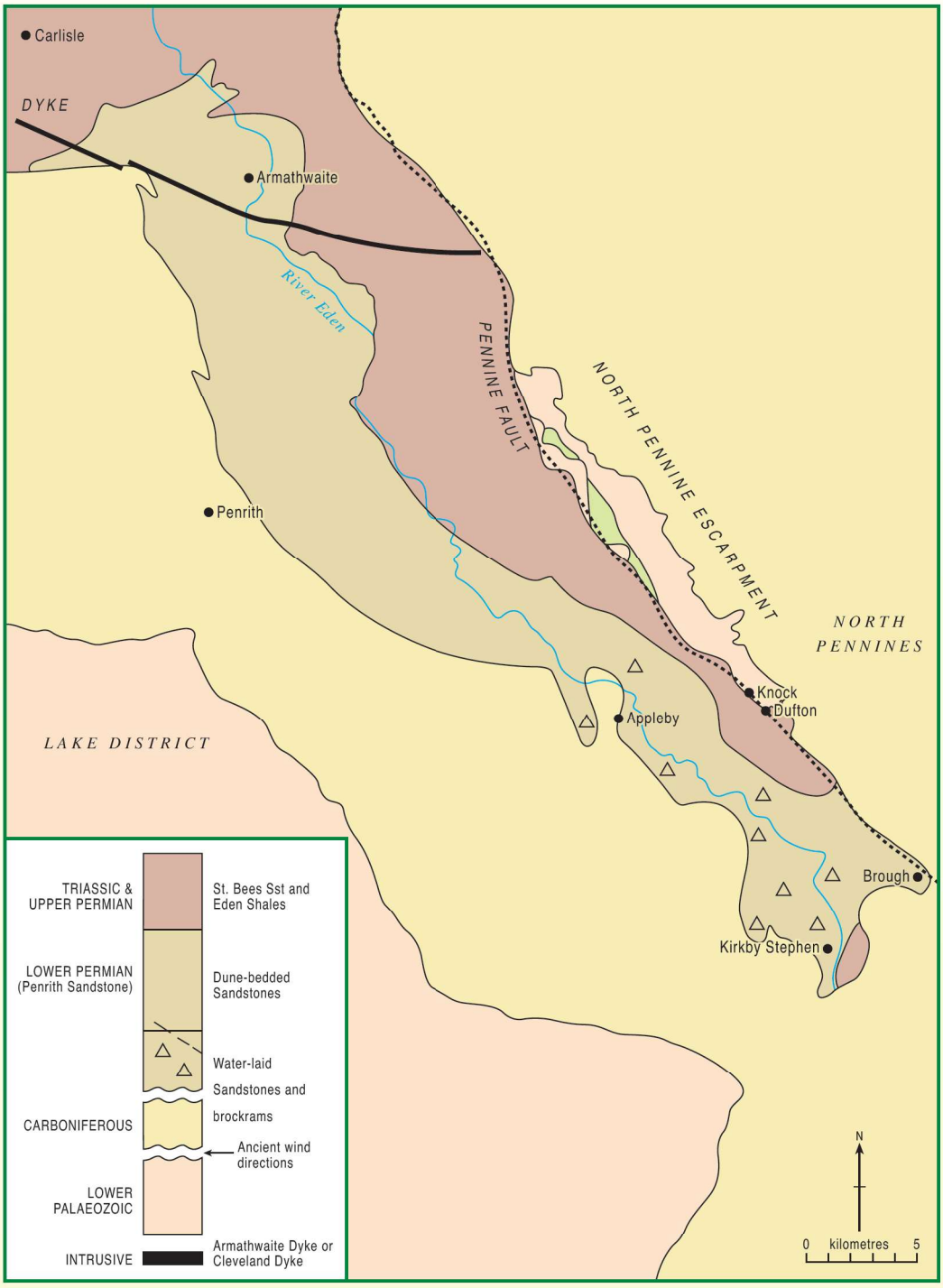
As the two continents collided through the process known as plate tectonics, enormous volcanic eruptions occurred lasting for around 12 million years. The volcanic rocks will be examined at Knock pike where many interesting features can be reaped from the rocks helping to understand the style of volcanism

The Ordovician volcanic rocks of Knock Pike are part of the Borrowdale Volcanics Group, named after the Borrowdale area of the Lake District. It is these rocks that give rise to the dramatic scenery. Much of the Borrowdale Volcanics Group is made from lavas, volcanic ash and large blocks of volcanic material including volcanic bombs (agglomerates). Knock Pike is made of predominantly volcanic ash (tuff) with a particle size of between 2mm to 64 mm. Volcanologists call such particles lapilli that means "little stones" in Latin. Often the heat of the newly deposited volcanic ash tends to cause the semi-molten material to flatten and the lapilli become welded. This is known as a welded tuff.

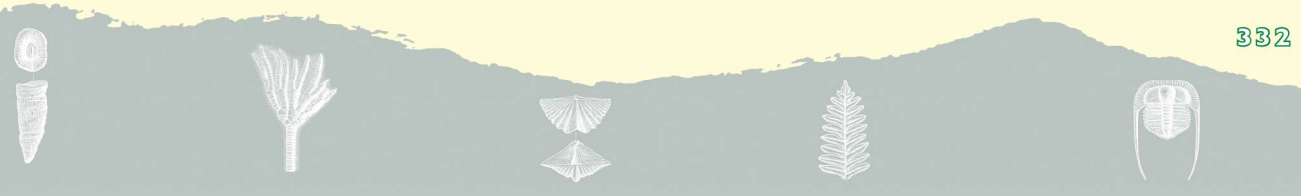


Dufton and Knock: Ancient Rivers and even older Volcanoes

Student Resource Sheet 1



Geological map of the Vale of Eden



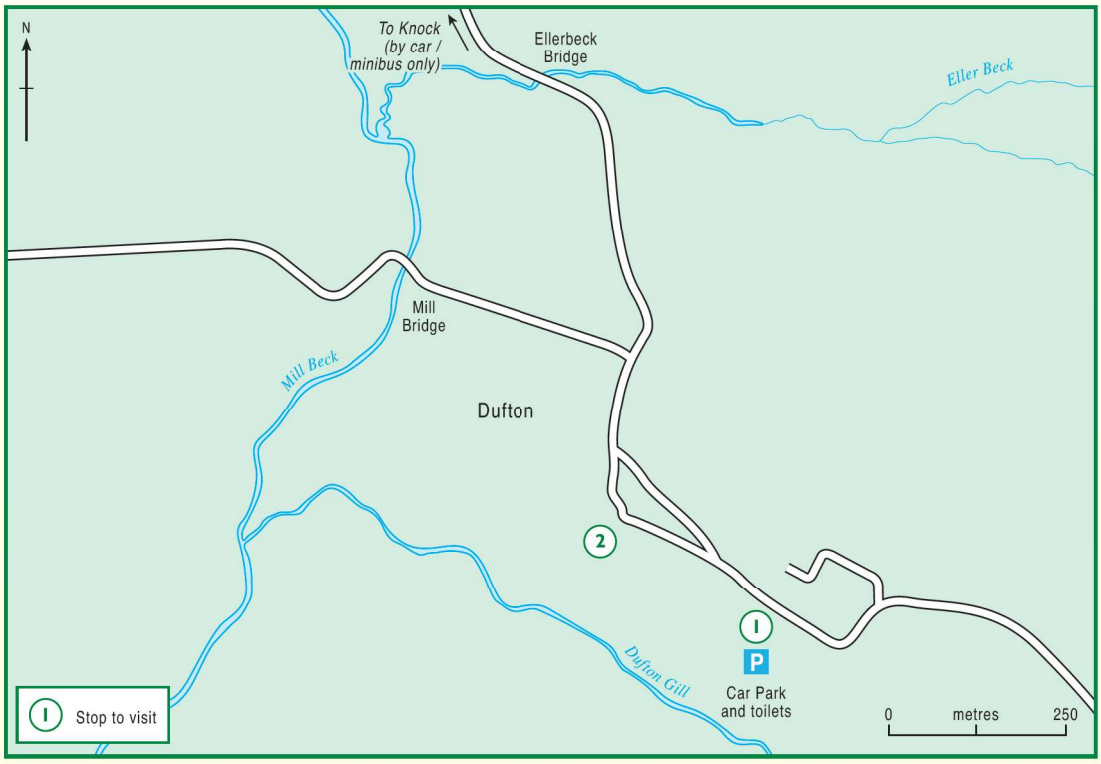
Dufton and Knock: Ancient Rivers and even older Volcanoes

Student Resource Sheet 2

ANCIENT RIVERS AND EVEN OLDER VOLCANOES

The exercises that you will do here will help you to:

1) Recognise sedimentary and igneous rocks
2) Understand how hot molten igneous rocks can be erupted from an ancient volcano
3) Recognise ancient environments from an understanding of the rocks



STOP 1: Dufton Red Sandstone blocks

Look carefully (using your hand lens) at the red sandstone blocks that make up the building (and many of the houses in the Vale of Eden) .This red sandstone is called Penrith Sandstone. It is a sedimentary rock.Why is the rock type sedimentary?

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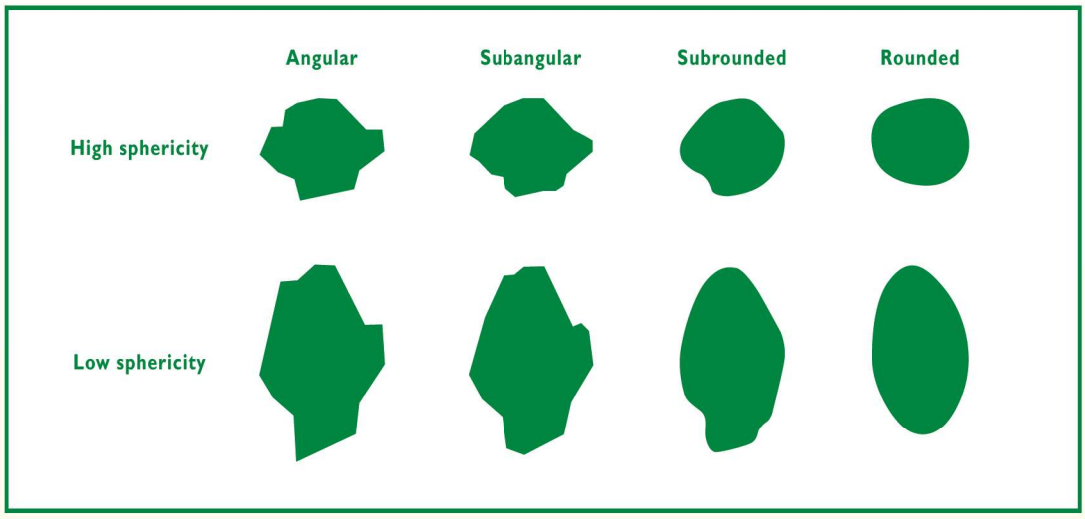
An important part in understanding ancient sedimentary rocks and interpretating the past environment is to determine the degree of rounding of grains.This can be undertaken by comparing the shape of the sedimentary rock grains to those on the table below.



Sprinkle a few grains of the Penrith Sandstone onto a white piece of paper and using your hand lens compare the shapes to those in the table above.

What shape are the grains in the Penrith Sandstone

What does the shape of the grains tell us about the length of time the sediment has been transported?

Can you recognise any minerals present.

Complete the rock table below:

Now make your way to the rocks along Wood Lane

STOP 2 Wood Lane

Look carefully at the red sandstone along the side of the path. This rock is called **St. Bees sandstone**.

Sprinkle a few grains of the St. Bees Sandstone onto a white piece of paper and using your hand lens compare the shapes to those in the table above

Answer the same question as for Stop 1 and complete the Rock table.

Rock Table	Stop 1: Penrith Sandstone	Stop 2: St. Bees Sandstone
Grain shape		
Length of time of grain transportation		
Minerals present		
Ancient environment of deposition		

Why is it important to recognise the differences between the two red sandstones?

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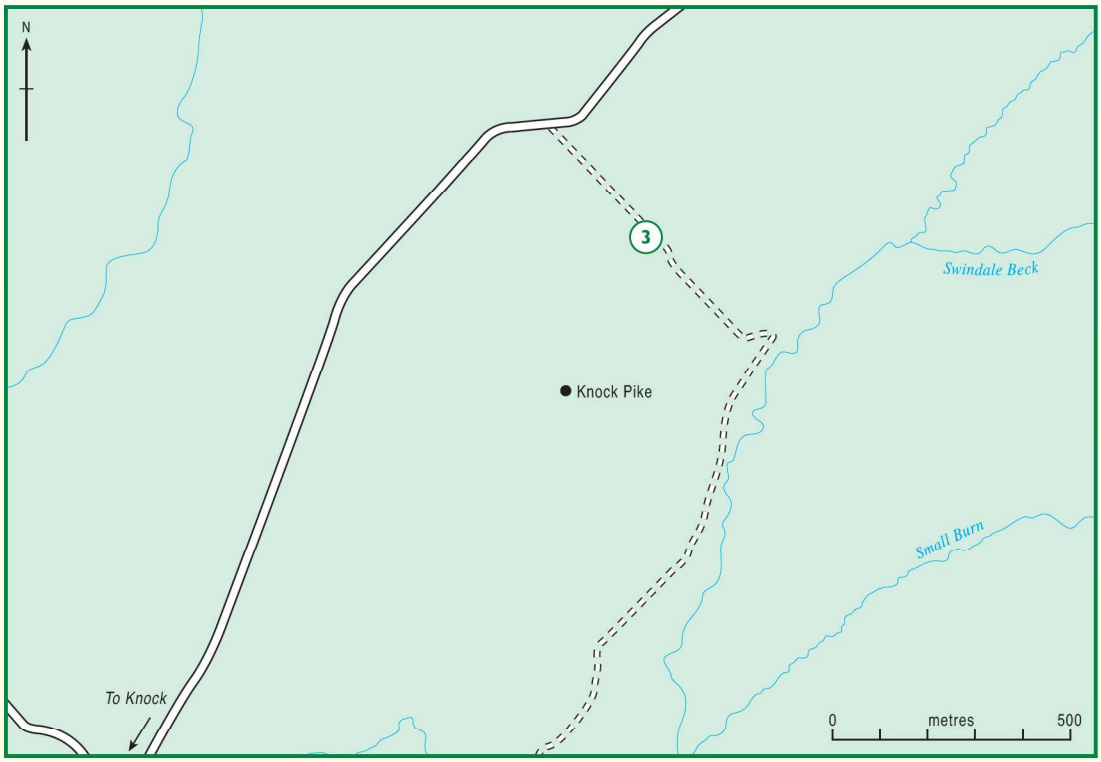
STOP 3: Knock Pike Quarry



The rocks that make up Knock Pike are the oldest found in the North Pennines Geopark. They formed towards the end of the Ordovician period at about 440 millions years ago.

Spend about 5 minutes looking at the loose fallen rocks at Knock Pike Quarry (it may help to use your hand lens).

These rocks are very different to the sedimentary rocks seen at Stops 1 and 2 in Dufton. Using some simple rock identification tests and your observations see if you can identify the rock. Make notes in the box below.

Use a hand lens to observe the rock carefully.
- What colour is it?
- Is it rough or smooth?
- Is it heavy or light in weight as a hand specimen?
- Is it shiny or dull?
- Can you see any crystals or grains?
- If crystals are they interlocking ?
- Are there any fossils?

Key identifying properties of rock:

Name of rock:

What rock type forms Knock Pike (Circle the correct answer)

Sedimentary **Metamorphic** **Igneous**

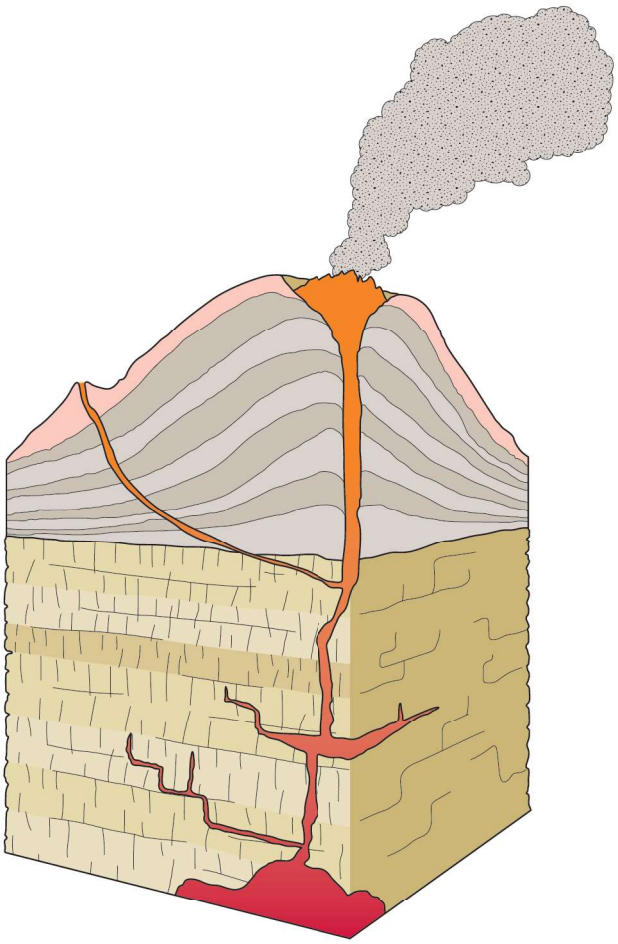
Well done if you have recognised the rocks as igneous. However, geologists would refine the name and call the rocks volcanic ash or tuff. Knock Pike is a special location as it provides geologists with a glimpse of what the environment was like 440 Million years ago.

We often forget that the apparently stable ground we walk on is in fact just a thin crust, floating on a gigantic sea of magma. If a crack appears in the crust, magma can escape along with poisonous gases and ash. This is how a volcano starts to form.

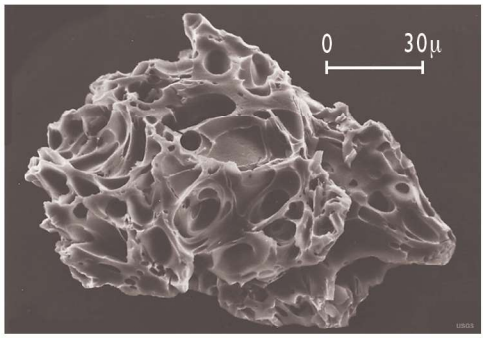
Using the names listed below carefully label the diagram of a volcano. On the diagram identify which of the volcanic deposits are represented by Knock Pike.

Parasitic cone **Vent** **Crater** **Lava flow** **Ash cloud**

Sill **Dyke** **Magma chamber** **Layers of ash and lava** **Side vent**



Look at the photography of a single particle of volcanic ash. Why are volcanic ash particles angular in shape?



Particle of volcanic ash.
It is important to note the scale and for you to understand how small ash particles are when erupted form a volcano.

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Read the following headlines from a newspaper article and answer the following question.

> *Alaska's Mount Redoubt volcano erupted five times overnight, sending an ash plume more than 9 miles into the air in the volcano's first emissions in nearly 20 years.*
>
> *Residents in the state's largest city were spared from falling ash, though fine grey dust was falling Monday morning on small communities north of Anchorage. It was advised that residents should stay indoors but if there was a need to go out, a mask was recommended.*

Why can volcanic ash cause respiratory problems?

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Large-scale volcanic activity may last only a few days, but the massive outpouring of gases and ash can influence climate patterns for years. The huge volumes of volcanic ash and rocks that now form Knock Pike must have had a significant impact up on the global climate in the Ordovician.

List four likely consequences of a large-scale volcanic eruption upon the global climate.

i. .....

ii. .....

iii. .....

iv. .....

The rocks were once quarried but it is now abandoned.

Based on your own observations of the volcanic rocks what do you think the rocks were used for?

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You have been asked as a consultant geologist to offer advice to the local council that are considering using the quarry to dispose household waste material.

You need to consider the potential geological problems with the site and how these may be overcome.

Write your answers in the table below:

Geological problems with the site	Solution to problems with the site

ORGANISATIONAL DETAILS

Location

Around the town of Appleby-in-Westmorland in the Vale of Eden

Target Group

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

Aim of Fieldwork

To demonstrate how Earth science (geology) principles can be illustrated out of doors, in a simple and safe way. It can be used to engage pupils in discussions about Earth processes and products. Particularly useful to sedimentary rocks and linkage to the rock cycle, weathering and understanding that the Earth is dynamic with faults and fractures (plate tectonics).

Practical Details

The exercises are all based around the town of Appleby, Vale of Eden. Appleby and the associated stops are located just outside of the North Pennines Geopark but as with all geology it does obey County borders or boundaries of a Geopark. However, the stops offer the best locations to view the rocks that were deposited as part of the ancient Permian desert that extended across the area. The exercises start in the centre of Appleby, and then require a short drive (approx 1 mile) to Stop 2 at Hoff Burrells on the B6260 (Parkin Hill). Stop 3 requires you to return to Appleby and then take the B6542 towards the A66 and follow the signs for Appleby Golf Course. Stop 3 is located out of sight of the road along George Gill.

Practical Details

- Parking - easy access and parking for a coach and minibus at all of the stops around Appleby
- Useful maps - Ordnance Survey Howgill Fells and Upper Eden Valley OL19

Materials Required

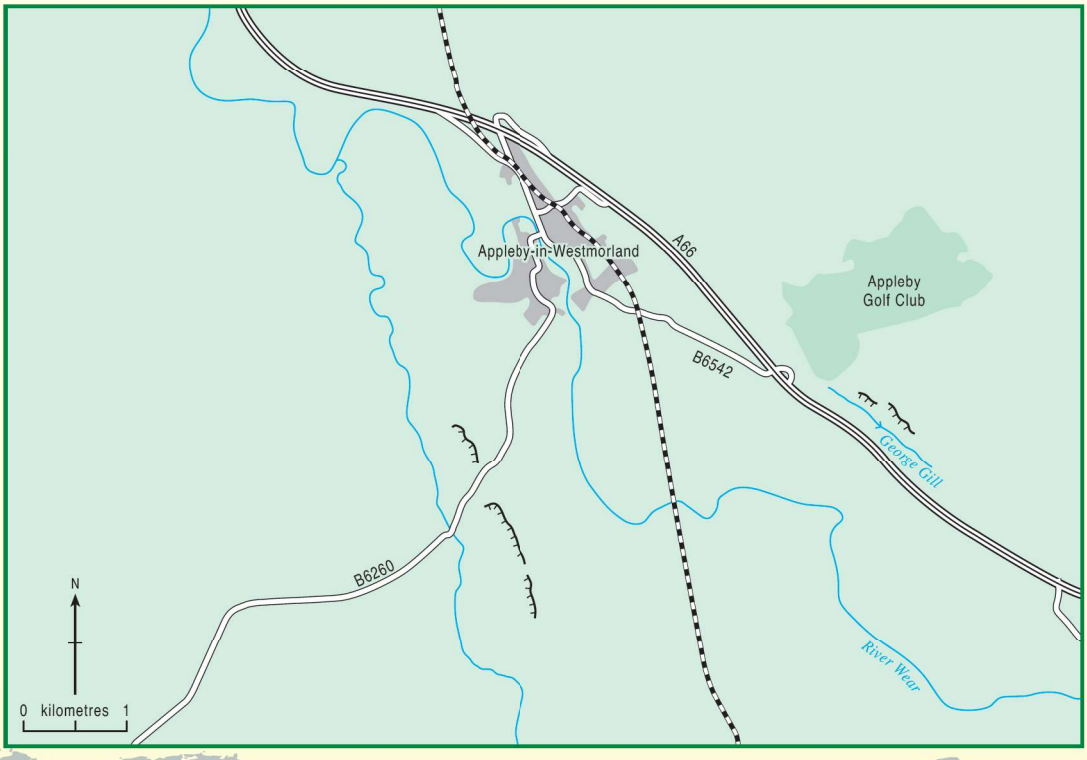
- Clipboard
- Pencil
- Hand lens (available from the Rock Boxes)
- Grain size cards (available from Rock Boxes)

Safety Issues

- Appleby and the surrounding area is reasonably protected compared with the winter weather that can be encountered in a lot of the North Pennines Geopark. However, staff and students should be prepared for bad weather conditions during the winter months and all need to wear suitable warm clothing and footwear.
- Refer to the Hazard Identification SheetGeopark. However, staff and students should be prepared for bad weather conditions during the winter months and all need to wear suitable warm clothing and footwear.
- Refer to the Hazard Identification Sheet

Appleby: A Hot and Arid Place

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 as car parking is restricted and narrow and other vehiceles 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 be careful when crossing the road at all the stops 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
Working close to rock faces	Many of the gravestones are very old and can be unstable. Do not climb or push any of the gravestones All students and staff	Warn about conditions and keep away from unstable high rock faces. Hard hats are advised if rock face is to be approached where it is higher than 2 metres
Steep grassy slopes	Extreme care should be taken when ascending or descending any steep grassy slopes and no running should be allowed All students and staff	Warn all students about the slope and supervise at all times. If unsure do not attempt or only in small groups
Animals in fields	Paths are ineven and may be slippery in wet weather. Students may slip and fall All students and staff	Warn students about any animals and keep away from the at all times

Plan of activities

The exercises are all based around the town of Appleby, Vale of Eden. Appleby and the associated stops are located just outside of the North Pennines Geopark but as with all geology it does not obey County borders or boundaries of a Geopark. However, the stops offer the best locations to view the rocks that were deposited as part of the ancient Permian desert that extended across the area.

The exercises start in the centre of the town of Appleby. STOP 1 Bondgate Scar. This is a good starting activating for observation and understanding sedimentary rocks.

You need to drive out of Appleby on the B6260 for approx 1 mile. STOP 2 Hoff Burrells Quarry provides an opportunity to sketch the larger scale structures associated with sedimentary rocks.

Return back to Appleby and then take the B6542 towards the A66 and follow the signs for Appleby Golf Course. STOP 3 is located out of sight of the road along George Gill. This stop provides evidence for proximity of the Pennine Fault with extensive fracturing in the sandstones (see geological map of Vale of Eden and North Pennine Escarpment).

Background Information

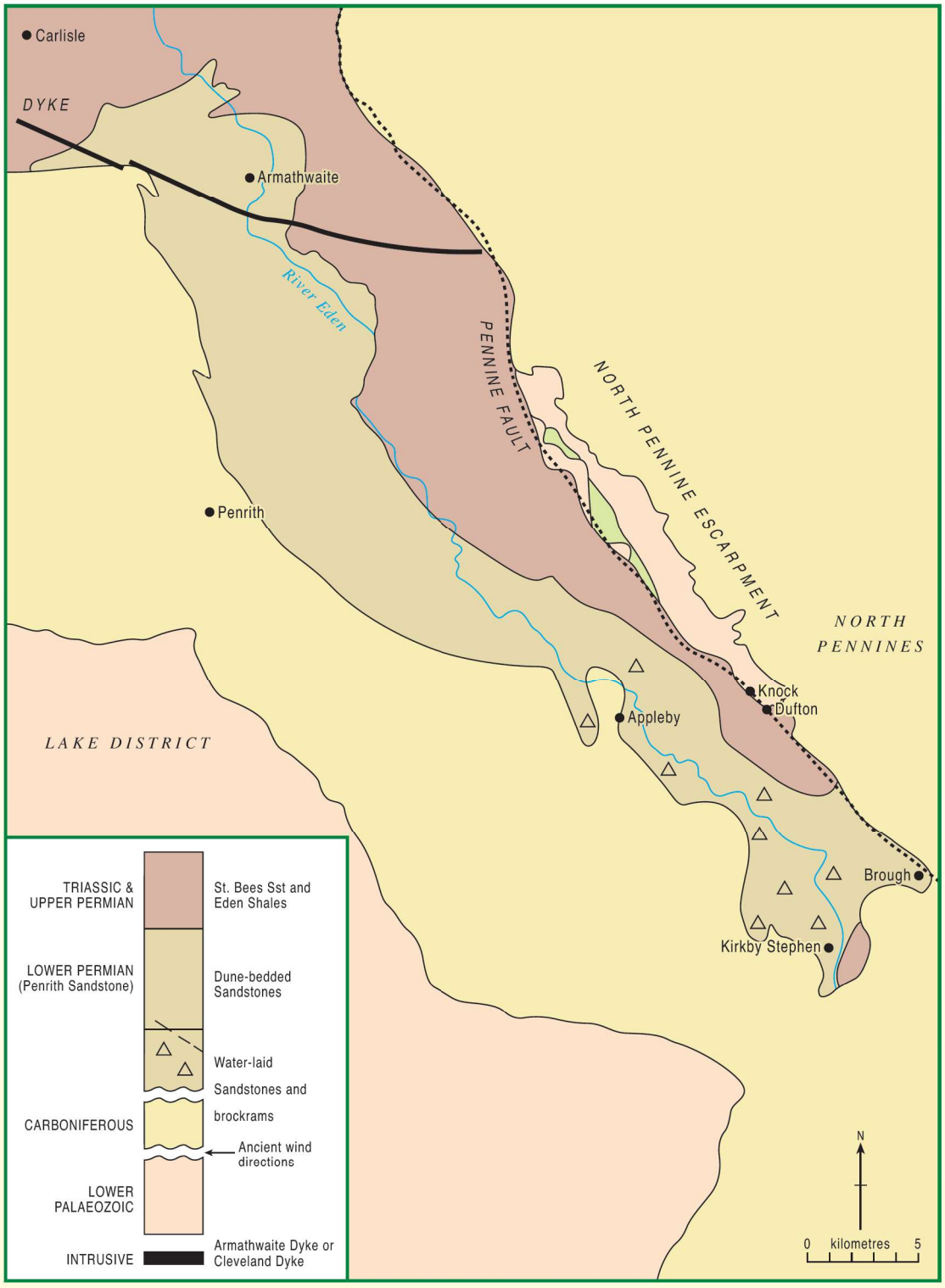
The Vale of Eden lying between the Lake District and the North Pennines is most notable for the warm red sandstone that gives the towns and villages of the Eden Valley their distinctive character. The sandstones were formed during the Permian and Triassic geological periods when the area was part of a vast arid desert and northern England was positioned just to the north of the Equator, in a similar position as the Sahara desert today. During the Permian the North Pennines was a hot and arid place with large desert dunes, rocky landscapes and some flash floods. During the Triassic the climate became more humid and flash floods and seasonal rivers spreading across the desert plains.

The oldest and most widespread sedimentary rocks are called the Penrith Sandstone, which can be found lying on top of the Carboniferous limestones that are a similar age as those seen in Teesdale and Weardale. It is understood to be more than 300 m thick in places but thins toward the North Pennines. The most striking feature of the sandstone is the steeply inclined layers that are visible in many exposures, the remarkable roundness of the grains when viewed with a hand lens and its red colouration. The ancient sand dunes were formed by wind-blown sand accumulating on the steep dune fronts which are thought to have slowly advanced to the North West. These steep dune fronts were then preserved as we see today in the rock faces (e.g. Bondgate Scar in Appleby). The extreme climate (intense day time heat and near freezing at night) created a loose rocky surface in the adjacent mountains. Rare rainstorms created flash floods that washed rock debris down steep gorges, to form large fans of sediment along the edges of the uplands where the gorges opened out on to the desert plain. These fans of sediment are called alluvial fans by geologists and the Brockram at Hoff Quarry, near Appleby is an excellent example.

Overlying the Pentrith Sandstone are the Eden Shales a sequence of shales, silts and some sandstones deposited in temporary salt lakes which evaporated in the arid climate to form thick beds of soft gypsum ($CaSO_4.2H_2O$) and more brittle anhydrite ($CaSO_4$). The gypsum and anhydrite is mined at Birkshead Mine [Long Marton NY665256] and then taken to Kirkby Thore for processing. The gypsum is ground to a powder and heated to evaporate water. Heating to approximately 160°C drives off a limited amount of water and Plaster of Paris is produced. The most important use of this type of gypsum is in the production of plaster and plasterboard for the building industry. Heating to above 200°C drives off all the water to produce the anhydrite which is used in the production of Portland Cement.

The upper part of the succession sees a return to red coloured sandstones called the St Bees Sandstone. The St Bees Sandstone will not be seen as part of this exercise but are frequently mistaken as Penrith Sandstone when used for house building. The St Bees Sandstone was deposited in the Lower Triassic (220 million years ago) by large rivers covering much of northern England.

Perhaps most interesting is the evidence from the Penrith Sandstones for movement of the Pennine Fault that forms the Pennine escarpment. At George Gill, near to Appleby Golf Course quartz veins in the Penrith Sandstone indicate fluid movement associated with fracturing of the earth's crust by the brittle fault movement and deformation. The quartz veining indicates that the fault was once active and affected the surrounding rocks. Such an occurrence is evidence for plate movement.



Geological map of Vale of Eden and Pennine Escarpment

Appleby: A Hot and Arid Place

Student Resource Sheet 1

Welcome to Appleby! The exercises that you will do here and in the surrounding area will help you learn the following things:

1) How to explain what you see scientifically (hypothesising).

2) To describe sedimentary rocks and recognise important details.

3) To apply your geology and scientific knowledge to understanding the past environment and what the landscape was once like.

STOP 1 Bondgate Scar, Appleby: [NY (35) 688199]

This old quarry which, was worked by hand for use as a building stone, is in the 'Penrith Sandstone' of Permian age (260 million years old). ***Do not attempt to cross the road, stay on the pavement at all times.***

Photograph of Bondgate Scar, illustrating the sedimentary structures and primary sedimentary bedding?

Q1. On the basis of the sedimentary structures you can see, what is the likeliest environment of deposition of this sedimentary succession?

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Q2.. ..... and agent of transportation?

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Q3. What can you deduce about the mineral composition, degree of sorting, maturity and cementation? (The photomicrograph below may help).

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Q4. What causes the red colouration of the Penrith Sandstone?

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Q5. What additional evidence do you now have for the depositional environment?

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STOP 2 HOFF QUARRY, BURRELLS: [NY(35) 676180]

This locality provides an excellent exposure of the lowest part of the Penrith sandstone, lying over Carboniferous rocks. These rocks are slightly older than those seen at Bondgate Scar.

First stand back from the rock face, and look at the geology.

Q6. Make an annotated sketch of the quarry rock face, the box over the page. Remember to include a scale and direction of view of your sketch. You may find it easier to provide a general outline and then add detail after answering some of the later questions.

Q6.

Sketch of Hoff Quarry

Q7 Describe the different sedimentary rock types you can see.

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Q8. What can you conclude about the degree of sorting and maturity of the sedimentary rocks. *(Hint: are they well sorted and rounded or something different? You can use the photo below to assist)*

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Now approach the rock face to look at the lithologies in detail

Q9. Look at the large grey pebbles. What are they made of?

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Q10. How would you describe the distribution of the various-sized pebbles?

(Geologists call these pebbles 'clasts' in this sedimentary rock)

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Q11. Can you see any unusual sedimentary features in the rocks?

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Q12. What conclusions about the mode of transport and depositional environment can you draw from your observations?

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Q13. Extensive reserves of gypsum & anhydrite occur in the Eden Valley and conformably overlie the Penrith Sandstones. The gypsum is mined at Kirkby Thore by British Gypsum and the anhydrite in small quantities at Newbiggin. The Kirkby Thore site has planning permission for underground workings of 1400 hectares. In what depositional environment would the gypsum and anhydrite occur and how does this relate to the Penrith Sandstone?

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STOP 3 GEORGE GILL BY APPLEBY GOLF COURSE: [NY(35) 718 188]

The George Gill exposure occupies a former glacial channel where excellent exposures of the Penrith Sandtone show a variety of sedimentary features.

Q14. The exposure has numerous white mineralized veins passing through it. What is the white mineral?

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Q15. What criteria did you use to recognise the mineral?

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Q16. What is the trend of the quartz veins and what caused their occurrence?

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Q17. You have seen the sedimentary structures at stops 1 and 2. Based on your previous interpretations and field observations what is the mean sediment transport direction. With the help of your group leader plot at least 10 measurements on to a rose diagram below.
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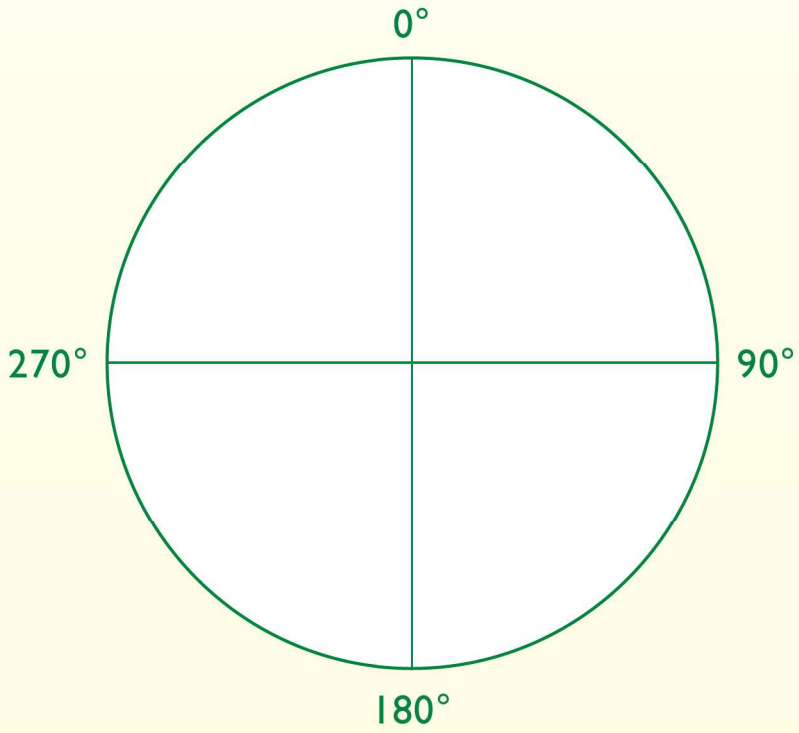






Appleby: A Hot and Arid Place

Follow-up Activity 1

DESERT SAND

Purpose

To explain why sand grains that have been transported by wind are generally better rounded than those transported by water.

Instructions

1. Choose four pieces of broken brick or limestone and sketch one piece.
2. Weigh them and use the roundness chart to give them a roundness value.
3. Place them in an empty container and screw on the lid firmly.
4. Shake vigorously for five minutes.
5. Remove the four largest pieces and sketch one of them and give it a roundness value.
6. Weigh only the four largest pieces.
7. Now repeat instructions 1 to 5 but put the four new pieces into the empty container and fill it with water. Shake with the same vigour as before.
8. Allow the pieces to dry overnight and then weigh them and sketch them and give them a roundness value.
9. Describe and explain your results

TEACHER SECTION

Requirements

Two plastic containers with screw lids which do not leak water

8 pieces of broken brick or limestone about 2cm diameter

Timer

Balance

Roundness chart

Notes

There is often some water leakage so if possible do the latter part of the experiment over a sink or over newspaper.

Check that the students shake for the full five minutes and with equal vigour for each container.

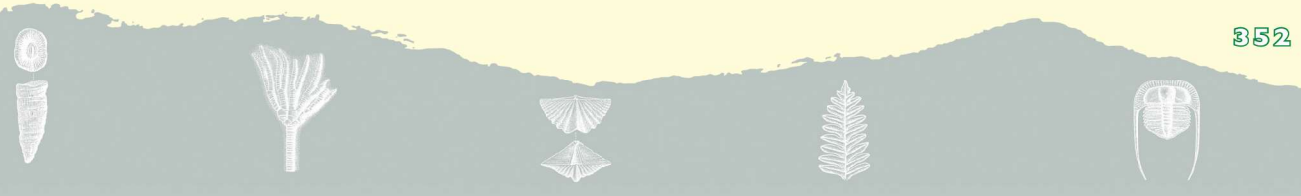
To make the experiment more rigorous use a lap counter to count the shakes on the dry run and then do the same number at the same speed on the wet run.

Results

Those shaken in water should be significantly less rounded than those shaken in air.

Time

Total about 30 minutes but samples need to dry overnight.



Appleby: A Hot and Arid Place

Follow-up Activity 2

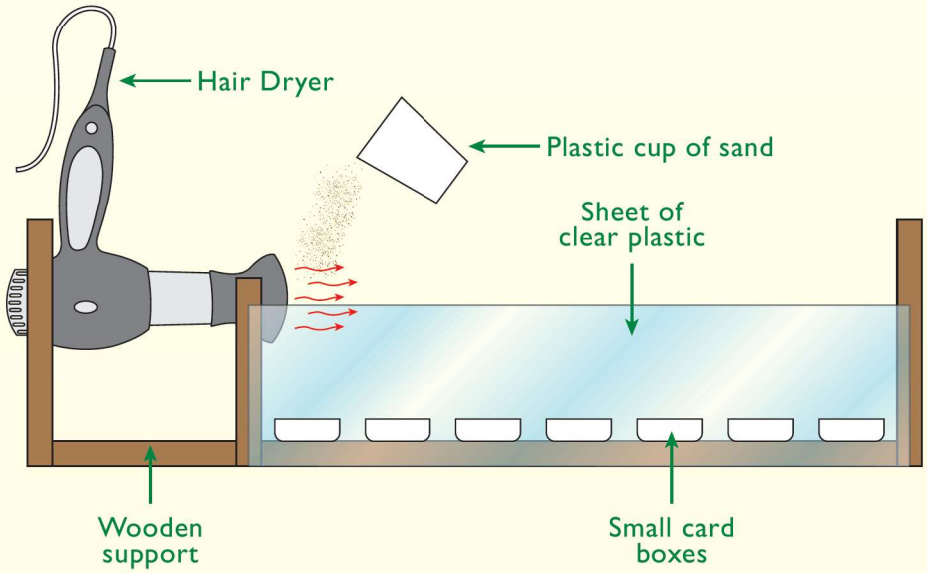
TRANSPORT BY WIND

Purpose

To explain how size, shape and density affect the ease with which grains can be moved by wind:

Instructions

In each activity the grains should be poured carefully and slowly from the appropriate container just in front of and above the nozzle of the hairdryer as in the diagram.



Exercise 1

Take the container of poorly sorted grains (200ml 0.125 to 4mm) and pour them out very slowly by shaking the container in front of the hairdryer.

Note the distribution of grains in the trays.

Use the grain size card to measure the maximum and average grain size in each tray.

Plot average grain size against distance from hairdryer.

Exercise II

Take the 0.1 g grains of quartz and mica and pour them in front of the hair drier.

Note how far from the hair drier each grain lands.

Plot a graph of number and type of grain against distance.

Repeat using the 0.2g grains.

Exercise III

Take the galena and pour it in front of the hair drier. Measure the volume in each box. Tip it all back into the original container.

Repeat with the sand.

Plot a bar graph of volume against distance for each.

Question

At Kalgoolie, in Australia, small grains of gold are found mixed in which larger grains of quartz sand in the wind blown sediment close to the outcrop of the gold vein. Explain why..

Appleby: A Hot and Arid Place

Follow-up Activity 3

MOVEMENT OF GRAINS

Purpose

Three experiments to determine the effect of shape, size, and bed roughness on the movement of grains.

General instructions

Place the grains 10cm from the top of the trough.

Place the tray under the top of the trough to catch splashes.

Place the container below the end of the trough to catch the grains.

Pour a jug of water quickly down the trough.

Observe and record how the grains move.

Measure how far the different shapes have moved.

Repeat so that you have 3 sets of results.

Exercise I Shape

Select grains of different shapes but one colour (all grains of the same colour have the same weight).

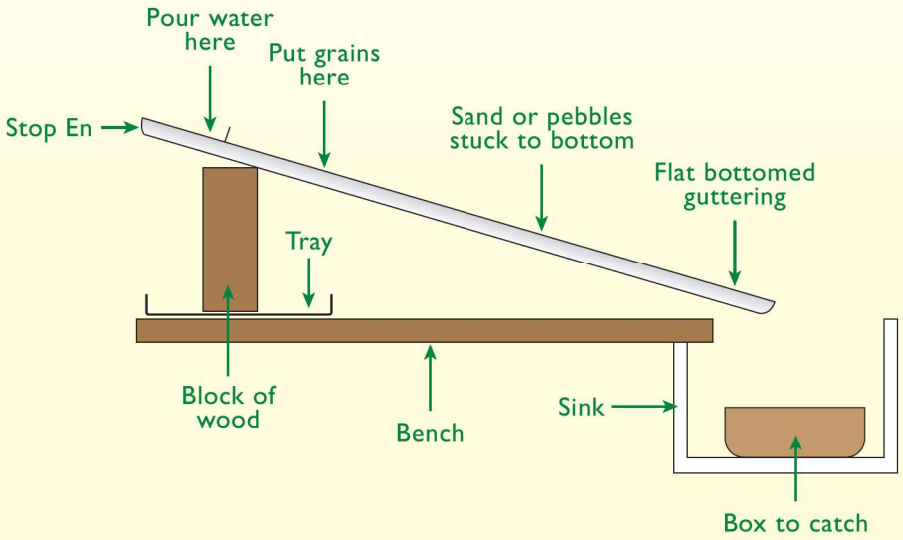
Exercise II Size

Select grains of different sizes but the same shape.

Exercise III Bed roughness

Select grains of the same shape but different sizes.

Repeat with different beds



TEACHER SECTION

Requirements

Fimo shapes of different shapes and sizes. At least 30 pieces are needed.

Fimo should be cut into pieces with the following weights: 2g, 3g, 6g. The different weights should be made from different coloured Fimo. The pieces of Fimo should then be moulded into the following shapes: cubes, spheres, discs, cylinders, pyramids and then heated.

Tape measure.

Clinometer to measure the slope.

Blocks of wood 10cm high to support the guttering.

2 litre jug.

3 one metre lengths of flat bottomed guttering each fitted with a stop end and each with sand or gravel grains of different sizes glued to the bottom.

Container to catch grains e.g. ice cream box. Tray (30cm by 40cm) to catch splashes

Making the equipment (30 minutes for 3 pieces of guttering)

Cut the guttering into 1m lengths and fit the stop ends. Cover the bottom with Unibond adhesive and then cover it with plenty of sand or gravel. Press the sediment into the glue and remove the loose pieces when the glue has dried. Suitable sizes are 16mm, 8mm, 4mm

Notes and results

Needs to be done next to a sink. This practical is good for designing, discussing and evaluating but the results are not repeatable.

Generally spheres travel fastest and by rolling. Cubes may roll or slide. Cylinders roll but end up caught on the side. Discs usually slide but sometimes flip. Pyramids roll or slide. The speeds and distances are very variable. Students should note in their evaluation that the water flow is not like a stream. It would be better to have a continuous flow of water but that would require a biggish pump.

Time

15 minutes for each activity

Cost

Approximately £8 for 2m of guttering and a small bag of pea sized gravel.

ORGANISATIONAL DETAILS

Aim of fieldwork

To demonstrate how Earth science (geology) principles can be illustrated out of doors, in a simple and safe way. It can be used to engage pupils in discussions about Earth processes and science.

Target Group

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

Location

Armathwaite village, Armathwaite Mill and Coombs Wood leading to Coomb Clints gorge.

Practical Details

This fieldwork day is based around Armathwaite and the River Eden. It will start from Armathwaite village, where walking over the bridge, you follow a path on the east side of the River Eden. After approximately 0.5 km you will reach Armathwaite Mill. (Stop 1). A further 0.5 km along the path the red sandstone gorge of Coombe Clints adjacent to Coombe woods is reached (Stop 2). To complete all the stops allow 3 hours. If travelling by coach it is advised for the coach to drop you off in the centre of Armathwaite and collect you at Longdales where the path returns to the main road. Parking can be difficult.

Materials Required

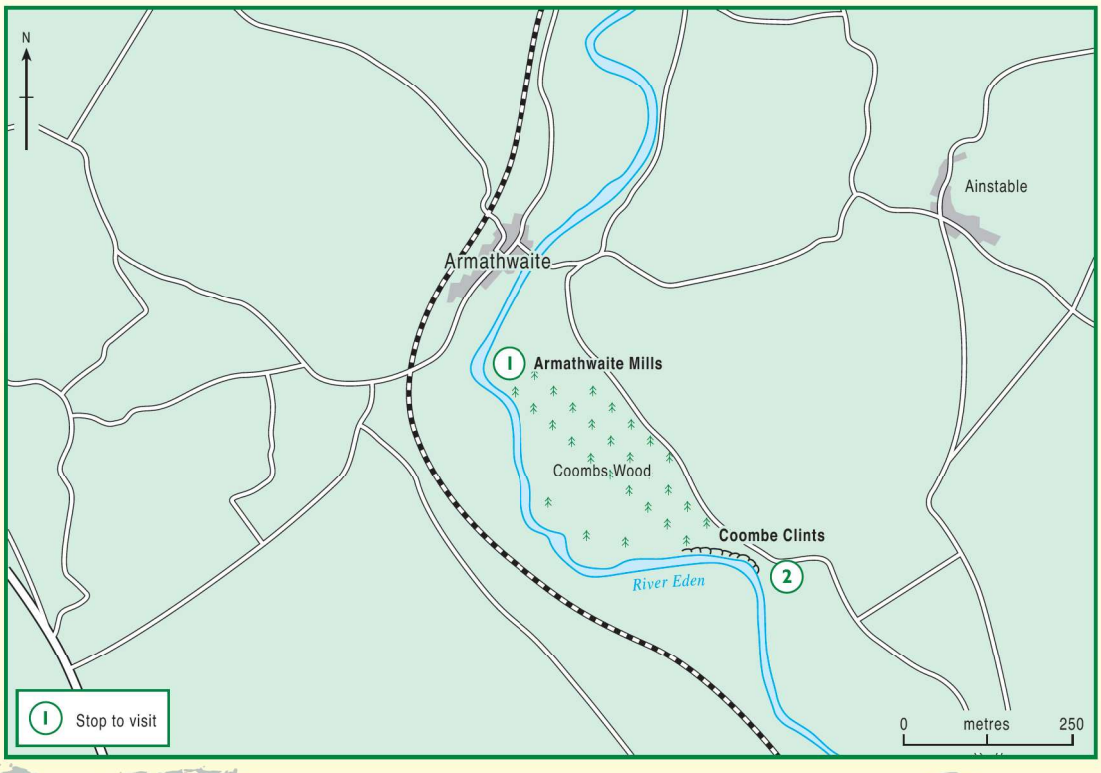
- Clipboard
- Pencil
- Copies of the student guide and worksheet
- Hand lenses - available through the Rock boxes
- Grain size cards - available through the Rock boxes

Safety Issues

- This region of Cumbria along the North Pennines escarpment can experience bad weather and like much of the North Pennines is an exposed area. Staff and students should be prepared for all weather conditions and all need to wear suitable warm clothing and footwear.
- Staff and students should keep a safe distance away from the edge of the River Eden at all times
- Refer to the Hazard Identification Sheet.

Armathwaite: Hot and Even Hotter

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	Students need to take care when getting off the mini-bus or coach whether in a car park or at the road side as other vehicles may be passing. All students and staff.	Supervise students getting off the coach or minibus and gather in a safe place.
Uneven paths	Paths are uneven and may be slippery in wet weather. Students may slip and fall. All students and staff.	Warn about conditions..
River Eden	Falling or sliding down the bank into the river. All students and staff.	Keep to the path and maintain a safe distance away from the river bank at all times.
Steep slopes	The path passes through Coombe Woods but to observe the red sandstone rocks you will need to follow paths through the woods to the edge of the river where you can rejoin a path All students and staff.	To supervise all students and to keep to paths through the woods. Caution needed when descending some of the steep slopes and no running.

Plan of activities

The activity works best in small groups of 6-10 pupils but there is sufficient space at each stop for whole classes.

Follow the path along the east bank of the River Eden for approximately 0.5 km *(~15 mins)*

Look at the dark blue-grey basalt that intruded into the Penrith red sandstones. This is particularly prominent in the River Eden at Armathwaite Mill where the basalt forms a natural weir approximately 25 m wide- **Stop 1** *(~60 mins)*

Continue to follow the path into Coombe Woods and along the east bank of the River Eden you will see Coombe Clints -**Stop 2** *(~ 60 mins)*. The gorge exhibits a 200 m long section of Penrith Sanstone .

Make your way back through Coome woods to the top of the hill and where the path meets the road at Longdales/ Coombeheads *(~10 mins)*

BACKGROUND INFORMATION

General Geology

From the Vale of Eden and northwards along the Pennine Fault escarpment red sandstones are used as a common building stone in many of the villages. The sandstones formed some 260 million years ago when the area was part of a large arid desert. The clues to unravel the history of these red sandstones can be found in natural rock outcrops and old quarries.

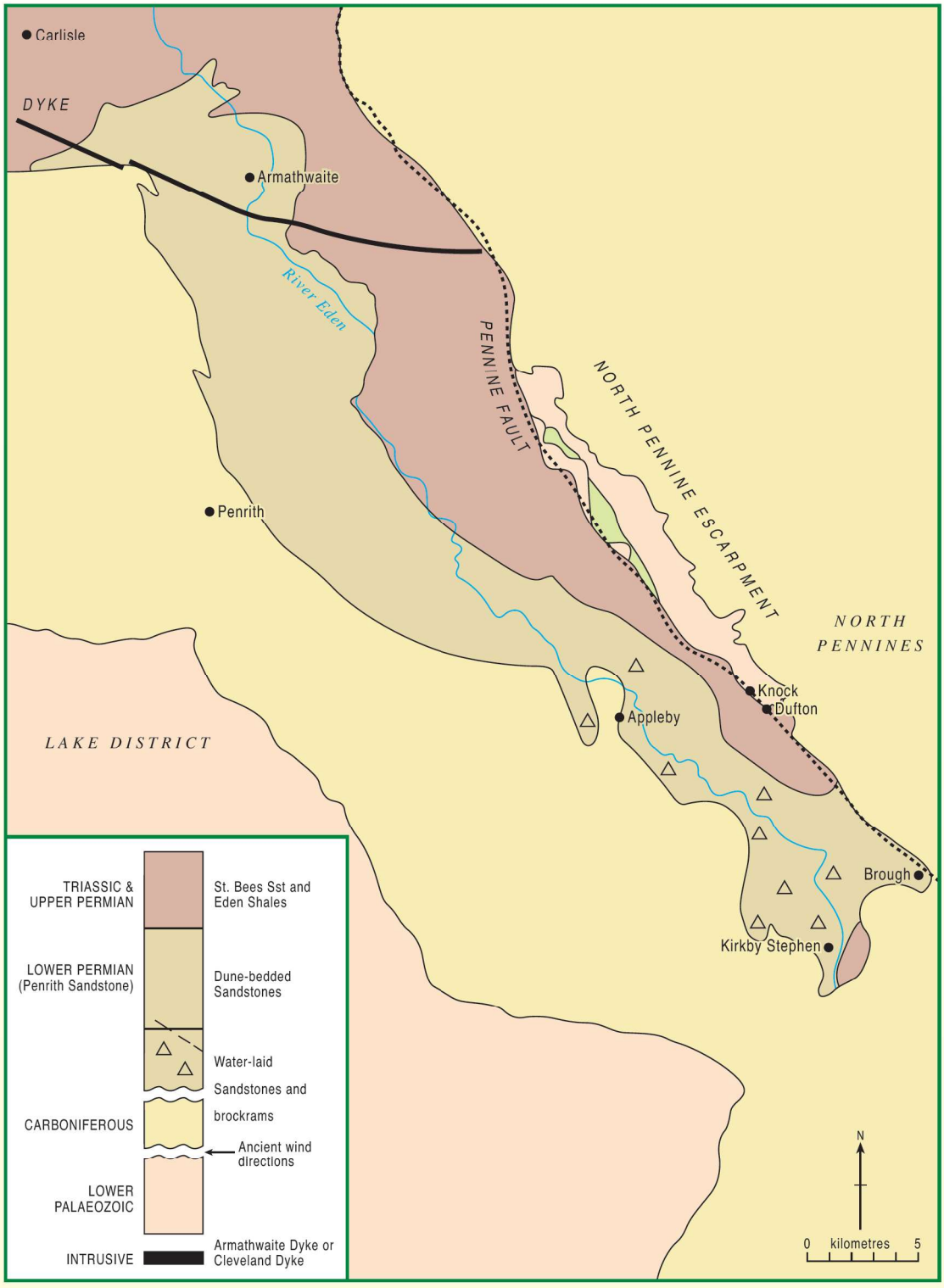
Cumbria lay in a region of hot deserts from 270 to 220 million years positioned just to the north of the Equator, in a similar position as the Sahara desert today. This time period is known to geologists as the Permian and Triassic Periods. To the west of the Eden Valley were the mountains, which today form the lake district, while to the east and south were ranges of rocky hills – forerunners of the North Pennines. During the 200 million years since deserts covered the Eden and Cumbria areas, erosion has removed much of the evidence but sufficient still remains to allow the geological history to be reconstructed.

Penrith Sandstone

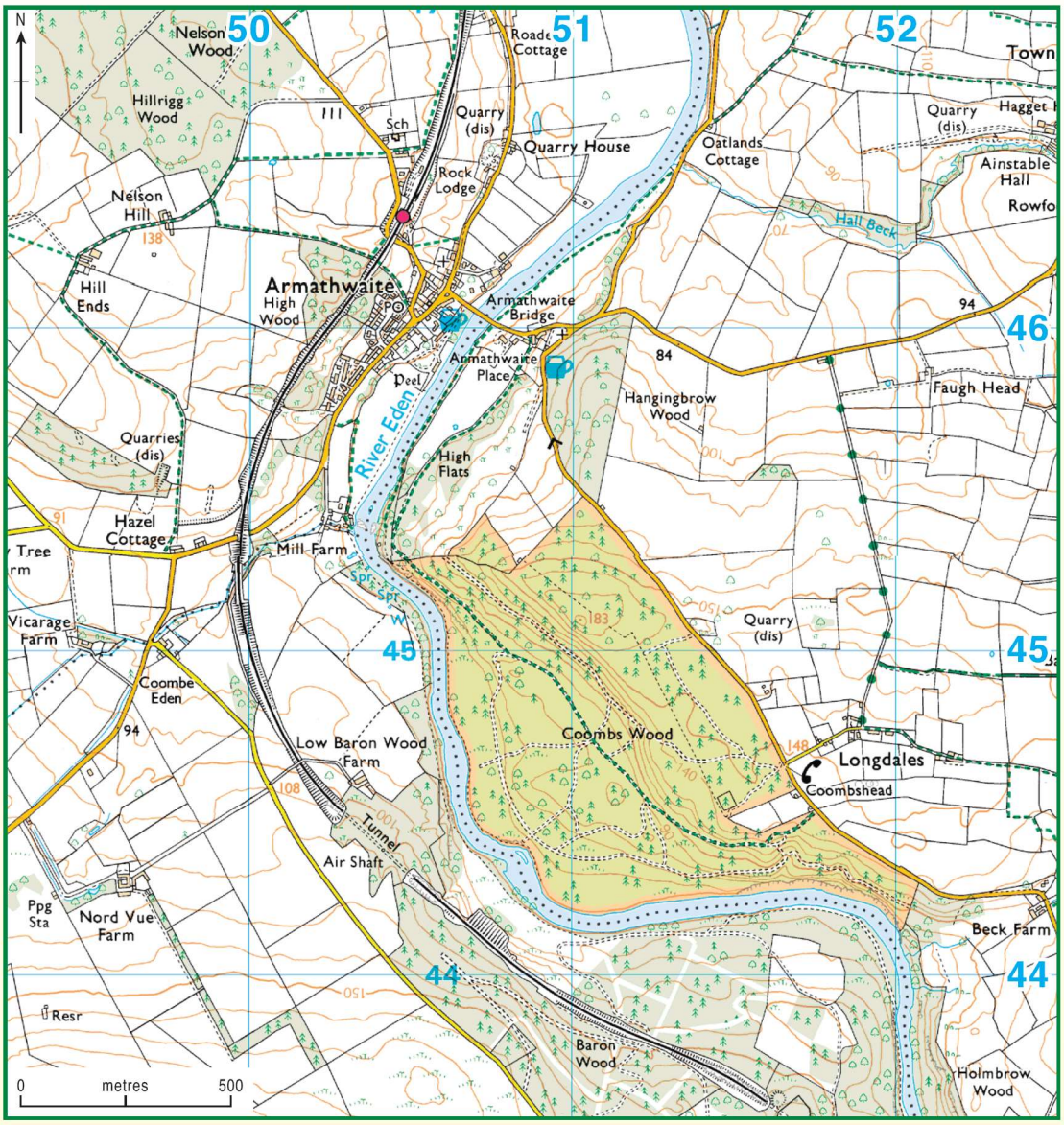
The oldest and most widespread of the rocks are the Penrith Sandstones of Permian age. Detailed observations of the Penrith Sandstone reveal clues about its desert dune origin. The very well rounded grains of sand (quartz) are characteristic of wind-blown sand from the relentless movement and sand blasting. The red staining that coats the grains of sand is a mineral called haematite (iron oxide) and shows that the environment must have been oxidizing (shortly after if not actually during deposition). This red colour typifies continental fluvial and desert dune sediments. However, the most noticeable feature of the sandstones are the large-scale cross bedding that record the ancient dune surfacse on the desert floor. The ancient sand dunes were formed by wind-blown sand accumulating on the steep dune fronts that advanced to the north-west, with the sand carried by easterly winds. Each dune is separated from the overlying one by a nearly flat surface which represents an erosion surface. Many ancient dunes can be seen at Coombe Clints as part of this geological activity.

More recently in geological time Cumbria has been affected by volcanic activity. This is characterised by vertical sheet of igneous rock intruded into the Penrith Sandstone seen at Armathwaite Mill. The dyke is approximately 25 m wide, is a hard, dark blue-grey basalt, with numerous mineral filled holes. The dyke has been dated at 60 million years old and related to the Tertiary age dykes of the Hebrides formed by North Atlantic spreading (plate tectonics). The Armathwaite Dyke continues into the North Pennines and on into North Yorkshire, where it is known as the Cleveland Dyke.

Dark grey–blue basalt of the Armathawite Dyke



Geological map of Vale of Eden and Pennine Escarpment



O.S. Map of Armathwaite





Ordnance Survey Map Symbols

ROADS AND PATHS

M1 or A6 (M) — Motorway

A35 — Dual carriageway

A30 — Main road

B3074 — 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

PC — 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

BP/BS — Boundary post / stone

CH — Clubhouse

FB — Footbridge

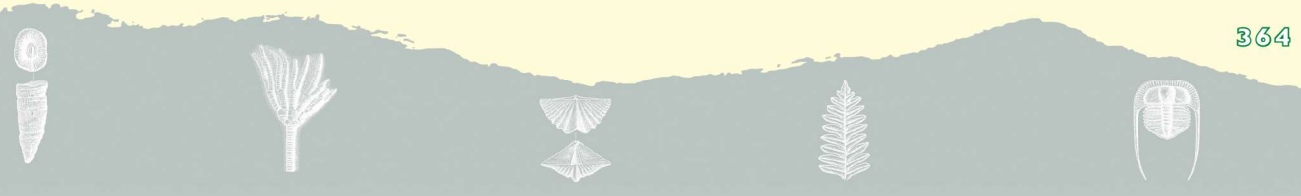
Mon — Monument

PO — Post Office

Pol Sta — Police station

Sch — School

TH — Town hall



Armathwaite: Hot and Even Hotter

Student Resource Sheet 1

HOT AND EVEN HOTTER: DESERTS AND VOLCANIC ACTIVITY!

Welcome to Armathwaite and the River Eden! The exercises that you will do here will help to :

1) Recognise the important differences between igneous, metamorphic and sedimentary rock types

2) Understand how hot molten igneous rocks can intrude into the Earth's crust

3) Recognition of ancient environments from an understanding of the rocks

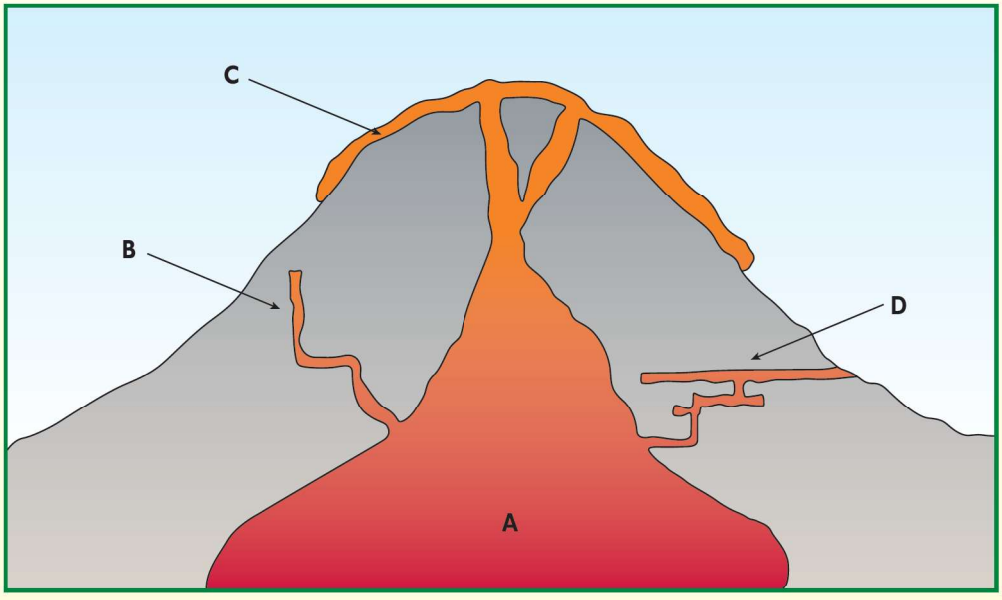
Study the geological map of the Vale of Eden and Pennine Escarpment. Make your way to Stop 1.

STOP 1 Armathwaite Mill (NY 503453)

Look at the rocks that make up the natural weir in the River Eden. The rocks are very resistant to erosion and are called the Armathwaite dyke. The Armathwaite dyke is related to volcanic activity some 60 million years ago in the Hebrides, Scotland.

Now answer the following questions:

The diagram below shows a volcano.



Name the four parts of the diagram

A ..... B .....

C ..... D .....

When rocks form at B, C and D there is change of state. What is this change of state?

…… to ……..

Rocks at C cool much quicker than at B. Which rocks do you think will have the larger crystals?

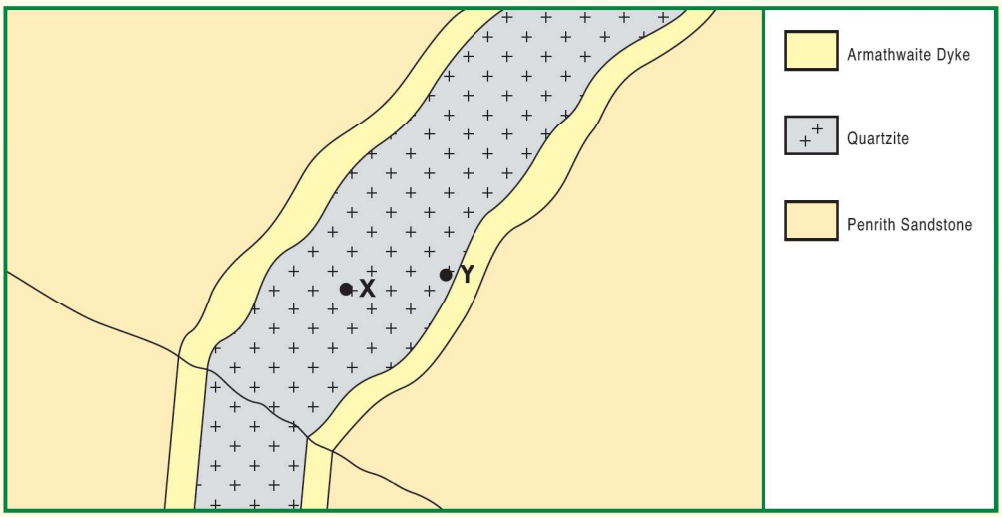
……

Which part of the volcano, A, B, C or D is the Armathwaite dyke a good example?

……

Look in detail at the rock that makes the Armathwaite dyke and complete the following questions:

The diagram below shows a close up view of the edge of the Armathwaite dyke. Using this sketch to help answer the following questions.



The igneous rocks that make up the Armathwaite dyke are best described as what? (Tick the correct box)

Intrusive ☐ **Extrusive** ☐

Which type of rock is sandstone? (Tick the correct box)

Metamorphic ☐ **Igneous** ☐ **Sedimentary** ☐

The sandstones immediately next to the Armathwaite dyke have been heated and baked to form rock called a quartzite.

What type of rock is a quartzite? (Tick the correct box)

Metamorphic ☐ **Igneous** ☐ **Sedimentary** ☐

Why are the crystals in the dyke larger at point X than at point Y?

.....

.....

.....

Assuming the average width of the dyke is approximately 20 m, it is about 10 km deep and extends for 430 km (from Scotland into North Yorkshire) what is the volume of magma that was intruded 60 million years ago?

It has been estimated that assuming the magma travelled at 1 m s^{-1} that it would have only taken 5 days to travel 430 Km and even less time to reach Armathwaite!

Follow the map to Coombs wood and carefully make you way down to the River Eden where you shall see a long line of cliffs called Coombe Clints.

STOP 2 Coombe Clints (NY 505452)

The long line of cliffs on the east bank of the River Eden are made of the red Penrith Sandstone.

The Penrith Sandstone is a sedimentary rock type that was formed 260 million years ago when the area was part of a large arid desert.

Clues to unravel the history of these rocks can be found by looking at the sedimentary rock very closely and observing the larger scale structures that are visible in the cliff sections.

Complete the following questions about sedimentary rocks and the Penrith Sandstone:

How is a sedimentary rock made from a layer of sediment?

.....

.....

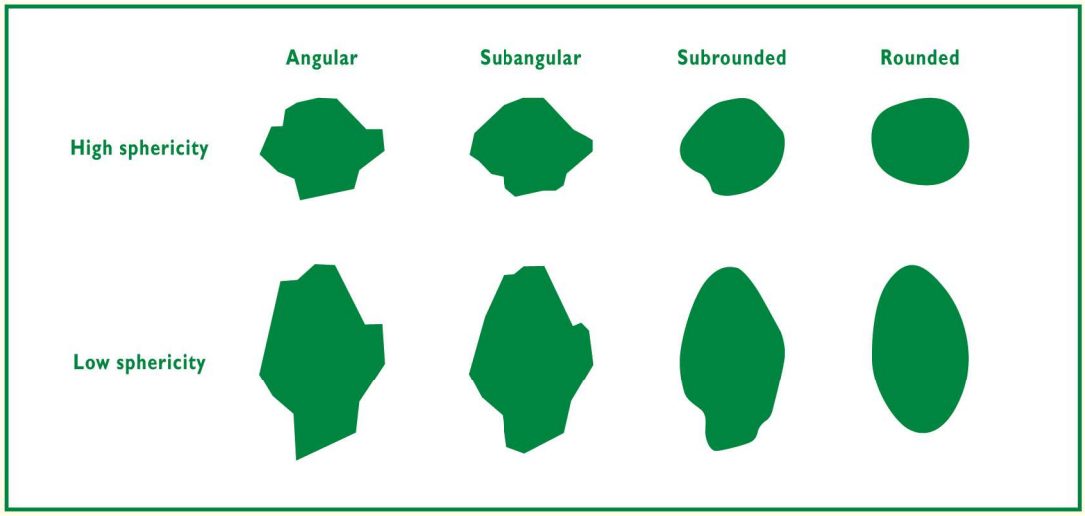
Would the oldest sedimentary rocks be at the top or bottom of the cliff section at Coombe Clints?

.....

.....

.....

Pick up a small sample of the sedimentary Penrith Sandstone. Look in detail at the rock and complete the separate Rock Data Sheet using the guide provided.



An important part in understanding ancient sedimentary rocks and interpretating the past environment is to determine the degree of rounding of grains. This can been undertaken by comparing the shape of the sedimentary rock grains to those on the table below.

Sprinkle a few grains of the Penrith Sandstone onto a white piece of paper and using your hand lens compare the shapes to those in the table.

What shape are the grains in the Penrith Sandstone?

.....

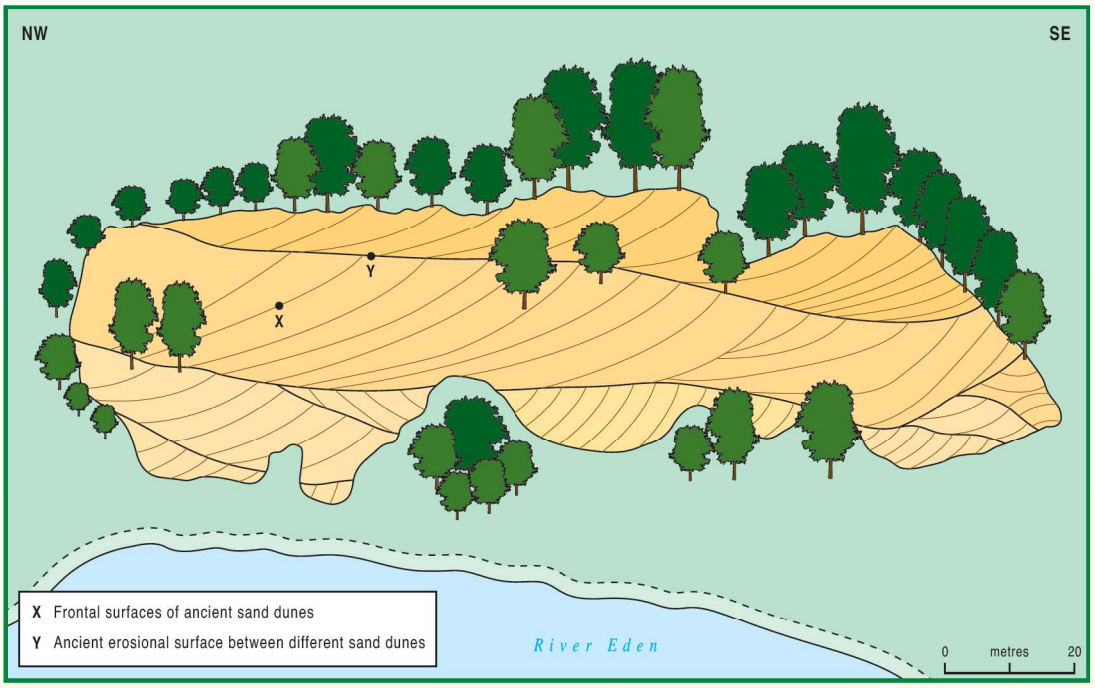
What does the shape of the grains tell us about the length of time the sediment has been transported?

.....

The large-scale sketch of Coombe Clints indicates a number of well preserved sedimentary structures.

Sedimentary structures are variations in layering of sediments that give clues about the past environment in which deposition occurred.

Look for some of these sedimentary structures using the sketch to help you and then answer the following questions about the ancient environment where the Penrith Sandstone was formed.



The large sedimentary structures are remnants of ancient large sand dunes. In what modern environment would you expect to find such features?

.....

.....

.....

What was the main means of transporting the sediment that made the Penrith Sandstone? Give your reasons why.

.....

.....

.....

Climb back to the top of the cliffs through Coombe Woods and follow the path to where the path meets the main road at Longdales.





Armathwaite: Hot and Even Hotter

Follow-up Activity 1

ROCK DATA SHEET

Use samples from North Pennines Rock Box for this activity

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 heavy or light in weight as a hand specimen?
- Is it shiny or dull?
- Can you see any crystals or grains?
- Are there any fossils?

Rock test 2 - Is the rock hard?
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 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?

Rock Test 5 – Use of grain size cards
Compare the grains of the rock to those on the grain size card. This provides an accurate measurement of grain size.

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, grain shape, If fossils present what do they look like

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 texture**.

Rock Name
Attempt to name the rock samples you collected based upon the tests and using the rock dial.

Exercise 1

Using your hand lens and the rock dial try to identify the type of igneous rock

Key identifying properties of rock:

.....

.....

.....

.....

Name of rock:

.....

.....

.....

.....

Exercise 2

Using your hand lens and the rock dial try to describe the sedimentary rock called Penrith Sandstone

Key identifying properties of rock:

.....

.....

.....

.....

Name of rock:

.....

.....

.....

.....

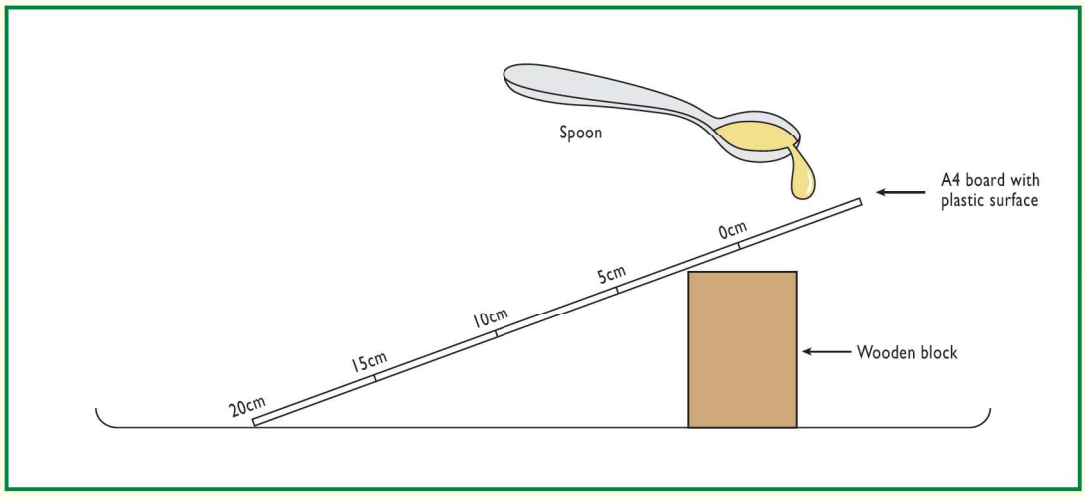
Armathwaite: Hot and Even Hotter

Follow-up Activity 2

SPEED OF LAVA FLOWS

Purpose
Four short experiments to determine independently the effect of the following variables on the speed of a lava flow: temperature, crystal content, angle of slope, and volume..

Instructions
General
1. Mark A4 boards with lines going across 10cm from the top end and then every 5cm.
2. Select slope and set up board on a tray on newspaper.
3. Stir syrup and record temperature.
4. Pour the syrup as shown in diagram onto the zero line.
5. Start the timer when the syrup reaches the 5cm line and record the time it reaches the other lines.



For temperature
Select a medium slope board. Remove jug from water bath or from heater and record the speed of flow for every 5°C drop in temperature.

For crystal content
Select a medium slope board. Use the syrup at 45oC and the sand at the same temperature. Add 5ml sand and stir it in. Repeat adding 5ml sand each time for four times.

For angle
Keep the syrup the same temperature but pour it onto 4 or 5 boards with different angles.

For volume
Keep the same angle and temperature but use different sized spoons.

Plotting your data
Plot four separate graphs and on each plot the speed of flow (Y) against each of the other variables (X) and draw your conclusions.

Question
Find out the viscosities of acid and basic magmas. Which type of lava will flow fastest?

Boards and supports for lava flows

TEACHER SECTION

Requirements
4 one pint jugs half full of Golden syrup heated to 65°C in a water bath
A4 boards preferably plastic covered, mine are made from old white board. Draw lines across at 5cm intervals as on diagram.
timers, thermometers, permanent felt tip pen.
Trays large enough to take the boards.
50ml fine sand heated to 45°C.
Strips of wood to support the boards at angles varying from 1 to 12 degrees.
Desert spoons. 2 5ml tea spoons, 1 table spoon

Notes
Syrup heats up quicker and cools more quickly if kept in the tin
Things can get quite sticky so have some newspaper to put the boards on and have some water and a cloth available. Clean the boards as soon as they are finished with.
The syrup should be about 45°C for the sand to be added otherwise it sinks too fast in the syrup.
Black treacle can be used, it has a more appropriate colour but requires a higher temperature (70 degrees)
Movement is very slow below 35 degrees.
Spoons should be put in the syrup beforehand and kept there otherwise they cool the syrup.
The syrup which has not had sand added can be reused.
When the flows are moving slowly it is possible for students to record upto three flows at the same time using either 3 timers or noting the clock time.
Glycerol can be used instead of syrup. Since its viscosity is known a much more mathematical treatment can be made, see Teaching Earth Science 2004 vol 28(3) 26.

Results
The syrup flows faster if the: the temperature higher because of reduced viscosity, the slope is steeper because of increase pull by gravity, the volume greater because of the greater distance of the main flow from the boundary layer. Sand slows the flow because of increased friction. Basic lava and will therefore flow more quickly.

Time
Between 30 and 60 minutes for one variable.

Armathwaite: Hot and Even Hotter

Follow-up Activity 3

DESERT SAND

Purpose
To explain why sand grains that have been transported by wind are generally better rounded than those transported by water.

Instructions
1. Choose four pieces of broken brick or limestone and sketch one piece.

2. Weigh them and use the roundness chart to give them a roundness value.

3. Place them in an empty container and screw on the lid firmly.

4. Shake vigorously for five minutes.

5. Remove the four largest pieces and sketch one of them and give it a roundness value.

6. Weigh only the four largest pieces.

7. Now repeat instructions 1 to 5 but put the four new pieces into the empty container and fill it with water. Shake with the same vigour as before.

8. Allow the pieces to dry overnight and then weigh them and sketch them and give them a roundness value.

9. Describe and explain your results

Boards and supports for lava flows

TEACHER SECTION

Requirements
Two plastic containers with screw lids which do not leak water
8 pieces of broken brick or limestone about 2cm diameter
Timer
Balance
Roundness chart

Notes
There is often some water leakage so if possible do the latter part of the experiment over a sink or over newspaper.
Check that the students shake for the full five minutes and with equal vigour for each container.
To make the experiment more rigorous use a lap counter to count the shakes on the dry run and then do the same number at the same speed on the wet run.

Results
Those shaken in water should be significantly less rounded than those shaken in air.

Time
Total about 30 minutes but samples need to dry overnight.

ORGANISATIONAL DETAILS

Aim of fieldwork

Aims

1) To describe and identify sedimentary rocks on the basis of their characteristics, including appearance, texture, colour and occurrence;
2) To identify different fossils in the limestones and recognise how they can be used to interpret ancient environments and;
3) To use the rocks to understand climate change today and in the geological past

Target Group

Key Stage 3 science and geography. However, the exercise could be easily adapted for key stage 4 (GCSE) science, geology and geography.

Location

Helbeck Quarry, Helbeck, Brough.

Practical Details

This is a half-day field trip based solely at Helbeck limestone quarry. The geological exercise starts from the south side of the quarry where a path leads from the road through a large metal gate along the edge of the quarry exposing grey limestones. The main part of the quarry has now been filled in and is no longer a hazard. The rock exposures are no higher than 2 m for much of the limestone section, but hard hats must be worn by all participants. To return to the coach or mini bus retrace the path back to the road. Parking is available at the end of the road outside of the quarry.

Materials Required

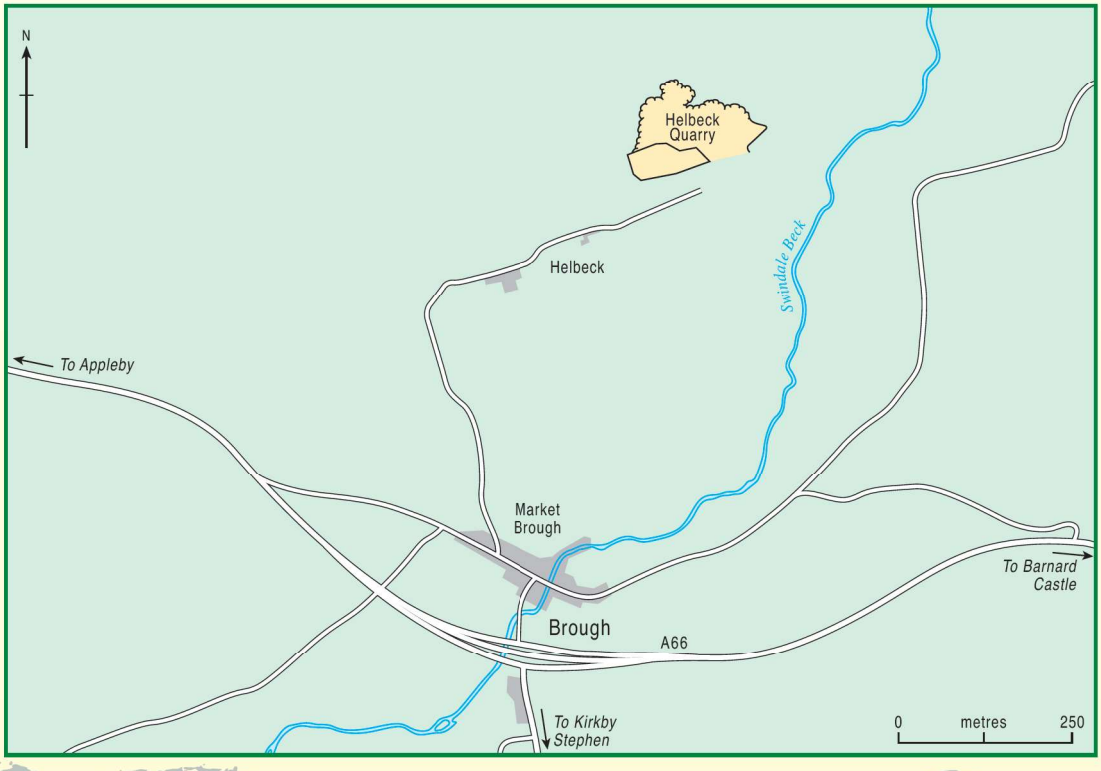
- Hard hats and flourescent waistcoats
- Clipboard and associated work sheets with this activity
- Fossil identification sheet
- Rock Dials
- Grain size cards if possible (available from the Geopark Rock Boxes)
- Hand lenses if possible (available from the Geopark Rock Boxes)
- Use of rock dials (optional)

Safety Issues

- This region along the North Pennines escarpment can experience bad weather and like much of the North Pennines is an exposed area. Staff and students should be prepared for all weather conditions and all need to wear suitable warm clothing and footwear.
- Staff and students should keep together at all times and not stray off the path at the edge of the quarry.
- Refer to the Hazard Identification Sheet

Brough: Tropical Sea, Fossils and Climate Change

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	Caution needed when getting off the coach or minibus. All students and staff.	Supervise students getting off the coach or minibus and gather in a safe place.
Uneven paths	Paths are uneven and may be slippery in wet weather. Students may slip and fall. All students and staff.	Warn about conditions.
Rock faces in quarry	Most of the rock faces are no higher than about 2m, but keep clear of any unstable rock faces. Most of the best samples to look at are as fallen blocks. All students and staff.	Hard hats to be worn at all times by students and staff.
Steep slopes	The path around the edge of the quarry ends with a fence and steep grassy slope. Do not climb the fence or attempt to descend the grassy slope. All students and staff.	To supervise all students and to keep away from the edge at all times.

Plan of activities

The activity works best in small groups of 6-10 pupils but there is sufficient space at each stop for whole classes.

- Follow the grassy and often boggy path along the southern margin of Helbeck Quarry and after 50 m you will see grey coloured rocks of the Carboniferous Robinson Limestone *(5-10 mins)*
- The limestone continues on for about 150 m. Suitably spread out into groups and describe the limestones using the rock data sheets and rock dials. *(40 mins)*
- Conduct a group discussion on how the limestone was identified *(15 mins)*. This is best identified with some weak HCl dropped on to the rock.
- Continue along the low cliff section until you reach a higher cliff section and the grassy path is now made of limestone. Large fallen blocks and the cliff section conatin many excellent fossil specimens *(5 mins)*.
- Make sure at least one fossil is drawn and the ancient environment is considered where these creatures use to live. Use the fossil identification sheet to assist *(40 mins)*.
- Observe the chemical weathering on the limestone and have a discussion about what this means for global warming. Then place this in the context of geological timeand especially the Carboniferous using the graph provided *(30 mins)*
- Make your way back to the coach or mini bus *(15-20 mins)*

BACKGROUND INFORMATION

General Geology

The North Pennines is mainly made up of rocks that geologists call the Carboniferous Period this occurred from around 350 to 300 million years ago. In the North Pennines the Carboniferous is dominated by sedimentary rocks that frequently occur in repeating layers of limestone, sandstone and shale. These layers give rise to the area's distinctive terraced hillsides and flat-topped hills. The rocks seen at Brough will focus on the limestones as they afford one of the best opportunities to see fossils in their ancient life position and reconstruct the ancient environmental setting.

A Tropical time

The seas where the limestone formed in the carboniferous teemed with life due to the tropical climate and palaeogeographical setting. Sea creatures such as corals, sponges, crinoids and brachiopods flourished in the clear, sunlit waters. When they died their remains accumulated as limy ooze and shelly fragments on the sea floor, eventually hardening to become the hard grey limestone we see today.

The limestone in Helbeck Quarry is called the Robinson Limestone and contains abundant examples of crinoids, corals and brachiopods. Many of these fossils are still in their positions and are exceptionally well preserved.

Limestone landscape

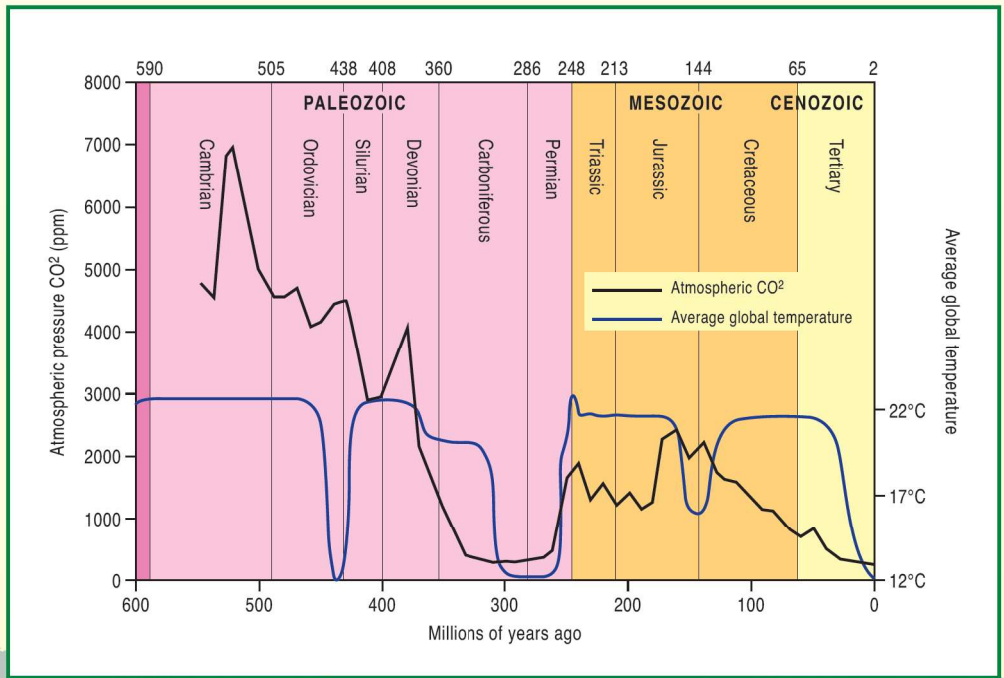
The Limestone landscape at Helbeck provides an insight to the unusual behaviour of limestone. It appears to be a hard and resistant rock to erosion but easily dissolves in acidic rainwater. This feature of limestone creates a 'Karst' landscape and can be easily seen in the Helbeck Quarry with weathering evident on many of the rock surfaces.

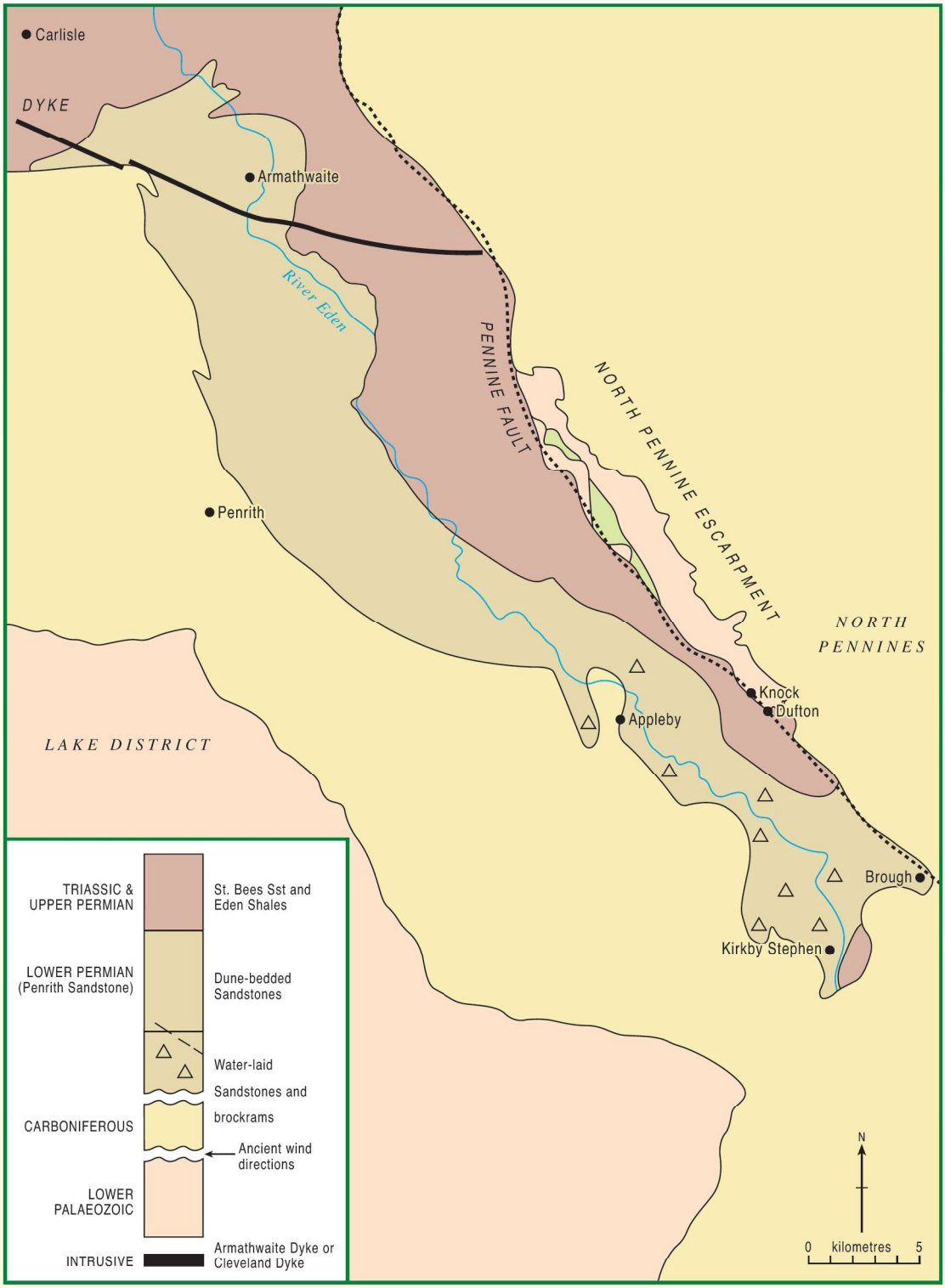
Limestone ($CaCO_3$) is readily soluble in weak acids. Rain water due to dissolved carbon dioxide from the atmosphere is really a weak carbonic acid. As the rain percolates through the ground it dissolves the limestone to form limestone pavements, sinkholes and cave systems.

The North Pennines does not contain any significant cave systems due to the limestones being relatively thin. However some small caves do exist and these tend to focused toward the Pennine escarpment.

Climate Change

Frequently geologists are best placed to appraise the effects of climate change on the Earth. Geologists deal with time scales of many hundreds millions of years and during this time the Earth has experienced many different climatic settings. The effects of modern acid rain can be clearly seen on the limestone in Helbeck Quarry and the surrounding North Pennines but frequently the detailed information locked in the rocks is overlooked. The rocks preserve details about the past climate and environments through the fossils that are preserved, the type of sediment and the relationship to the surrounding layers of sediments. It is possible to even reconstruct the past atmospheric CO_2 through geological time. As can be seen from the graph below there has been many times in the Earth history when CO_2 has been significantly greater than at the present day and this will be explored in greater detail when appraising the limestones in the quarry.



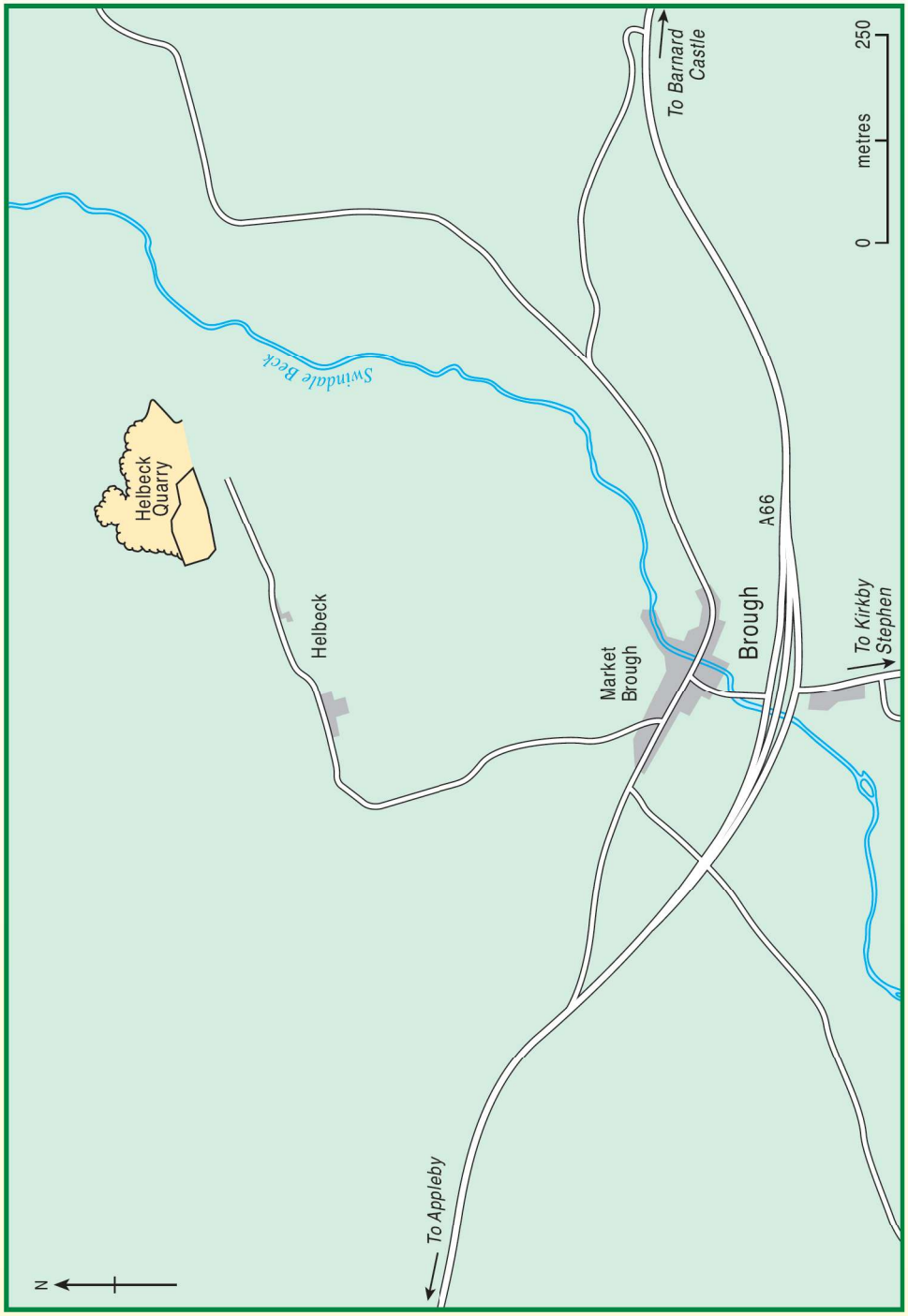


Geological map of Vale of Eden and Pennine Escarpment

Brough: Tropical Sea, Fossils and Climate Change

Student Resource Sheet 1

MAP OF BROUGH AND HELBECK QUARRY







Student Resource Sheet 2

ROCK DATA SHEET

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 heavy or light in weight as a hand specimen?
- Is it shiny or dull?
- Can you see any crystals or grains?
- Are there any fossils?

Rock test 2 - Is the rock hard?
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 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?

Rock Test 5 – Use of grain size cards
Compare the grains of the rock to those on the grain size card. This provides an accurate measurement of grain size.

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, grain shape, If fossils present what do they look like

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 texture**.

Rock Name
Attempt to name the rock samples you collected based upon the tests and using the rock dial.





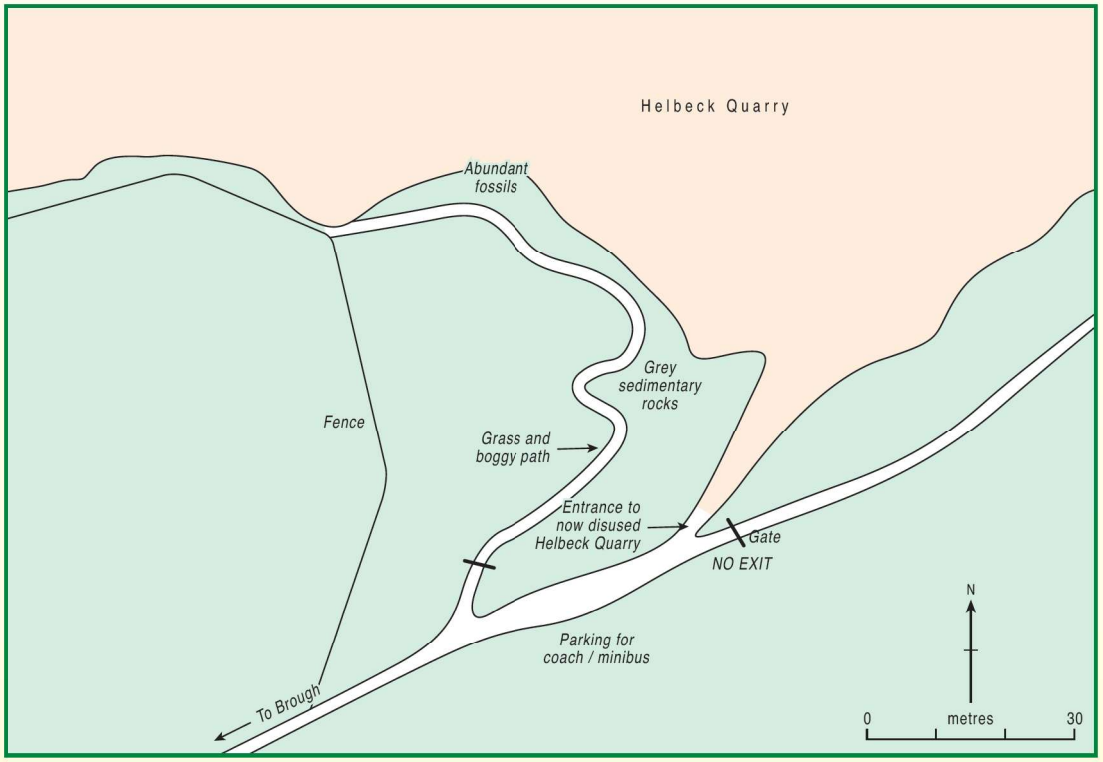
TROPICAL SEAS, FOSSILS AND CLIMATE CHANGE

HARD HATS MUST BE WORN IN THE QUARRY AT ALL TIMES

Welcome to Helbeck Quarry! The exercises that you will do here will help you to:

1) Describe and recognise of sedimentary rocks in the field
2) Understand the importance of fossils in sedimentary rocks
3) Recognise how an understanding of the Earth and its processes can help us to understand climate change

Study the map of Helbeck Quarry and make your way to look at some of the grey rocks that make up the quarry



Rocks of the Quarry
Spend about 10 minutes looking at loose fallen sedimentary rocks and the sedimentary rocks that make up the quarry wall. Use the rock data sheet to help carry out tests for identification

Helbeck Quarry is mainly made up of rocks that geologists call the Carboniferous Period this occurred from around 350 to 300 million years ago.

Now answer the following questions about the sedimentary rock you have seen.

Using your hand lens and the rock dial try to identify the type of igneous rock

Key identifying properties of rock:

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Name of rock:

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How is a sedimentary rock made from a layer of sediment?

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Would the oldest sedimentary rocks be at the top or bottom of the cliff section at Helbeck Quarry and why?

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Where does the cement come from that is used to stick the grains together in this sedimentary rock.

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Explain why the occurrence of limestone often indicates that the land was once under a warm, shallow sea.

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Fossils in the Rocks

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.

Circle the rock type you have the best chance of finding fossils in

Igneous **Sedimentary** **Metamorphic**

Draw at least one fossil you find in the rocks and use the fossil identification sheet to recognise some others.

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

Discuss in your groups what ancient environment you think the fossils you have found use to live in? Give your reasons.

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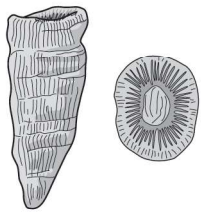
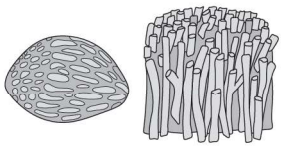
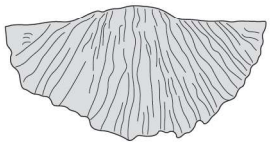
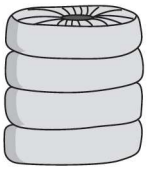
FOSSIL IDENTIFICATION SHEET

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		

ROCKS AND CLIMATE CHANGE

Many geologists carry small bottles of hydrochloric acid to identify limestones in the field. The limestone reacts with the acid to produce carbon dioxide, water and a salt. If the rock fizzes when a little acid is dropped on it, the rock contains calcium carbonate. Most other sedimentary rocks show no reaction. You have already undertaken this test.

When carbon dioxide dissolves in rain water it forms a weak acid which reacts with limestone. The limestone may dissolve away over many thousands to millions of years and may form fissures and caves.

What features have you observed in the grey limestones that it is slowly dissolving away due to acid rain.

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Carbon dioxide is one of the main greenhouse gases and is contributing to global warming, but why are the amounts of carbon dioxide in the environment increasing?

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How is carbon dioxide removed from the Earth's atmosphere?

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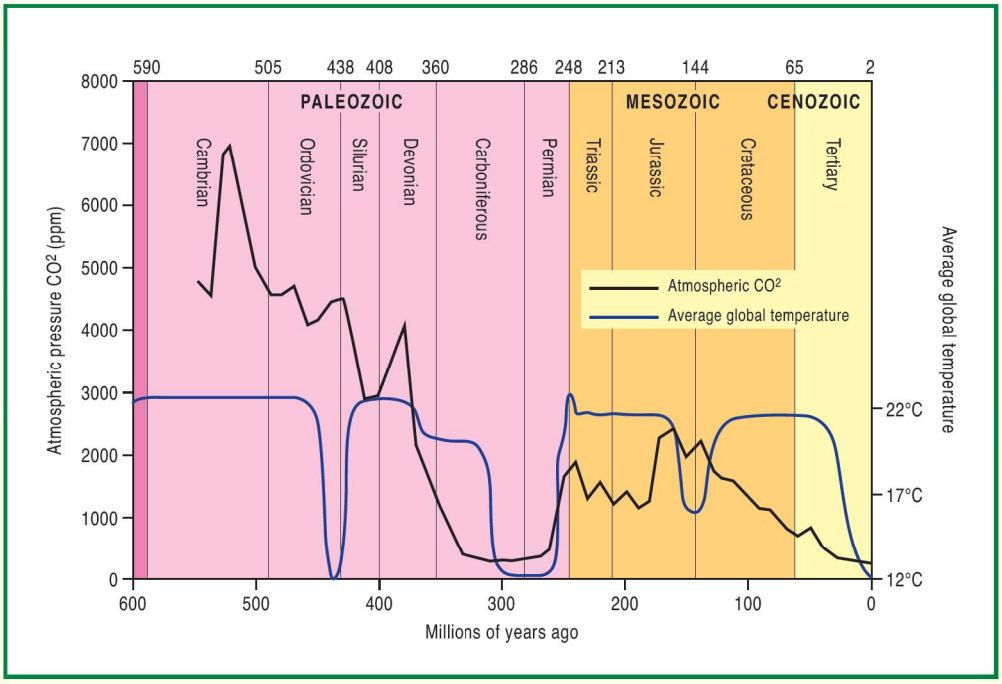
Now look at the graph below of the past levels of CO_2 in the Earth's atmosphere through geological time.



Why do you think the levels of atmospheric carbon dioxide have varied through geological time?

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Hypothesise why you think during the Carboniferous Period atmospheric carbon dioxide levels fell to one of the lowest levels throughout geological time.

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