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Introduction

☛ **In order to complete these field work exercises you will need to ensure each pupil is provided with: a clipboard and copies of the worksheets; each small work group of pupils has a tape measure, a hand lens, a grain size comparitor card (or graph paper) and a compass.**
In addition group leaders will need a small plastic bottle of dilute HCl and a small plastic bottle of water to demonstrate porosity and a tyre depth gauge. A digital camera will also be useful.

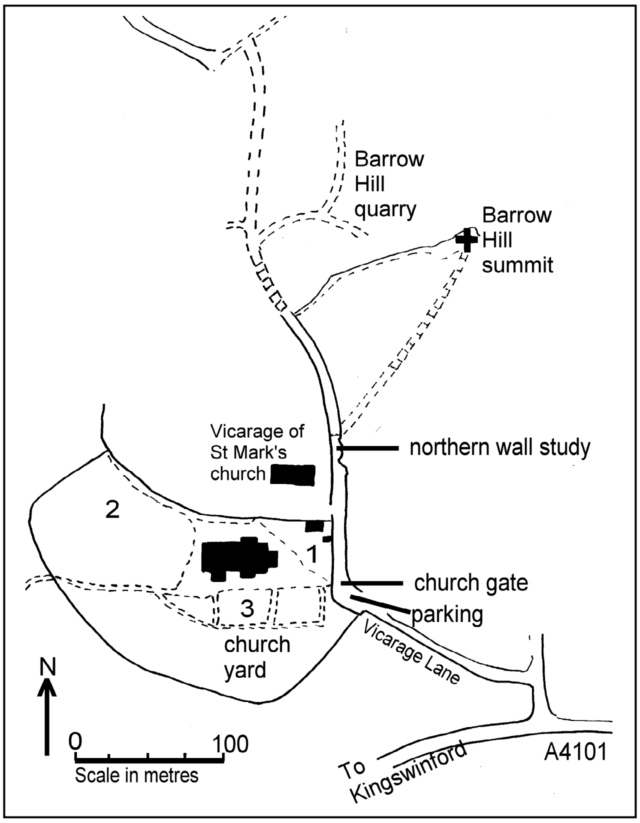

Figure 1. Map of the field sites at Barrow Hill

☛ **Please comply with any arrangements you made with the church authorities when setting up the visit.** The first site is the churchyard at St Mark's. Please remind pupils of the following:

- the work can be carried out whilst behaving in an appropriate and sensitive manner (not walking over grave sites for example);
- that some of the people also present in the church grounds may be recently bereaved and upset, or just seeking a place of quiet reflection;
- making loud noise, consuming food, drink and leaving litter are not appropriate in such a place;
- whilst it is permissible to observe, sketch and measure things in the churchyard, damage to any of the monuments, or disrespect of the deceased, is just not acceptable.

(Discrete use of a small drop of HCl on **a back surface** of a (limestone or marble) monument by a member of staff is appropriate. **Use the water to wash the spot after the test.)**

☛Group sizes above about 15 are probably too big. Split a larger party into appropriately sized subgroups, and then allocate workgroups of 3 or 4 to work on different areas of sites 1 and 2. Groups can then be rotated through the tasks at sites 1 and 2. Each task here should take about 30 to 40 minutes.

Remind the pupils that they are here to collect data to test hypotheses, and to recognise different rock types (igneous, metamorphic and sedimentary).

Site 1. St. Mark's Churchyard:

Task 1: Investigating weathering at St Mark's.

For task 1 group leaders may want to choose one or more of the following suggested hypotheses they want their groups to tackle:

1) Did the stone used to make monuments in this churchyard vary over time?
2) Does amount of weathering that has occurred vary with the type of stone used?
3) Does the rate of weathering of marble vary with the direction the marble surface is facing?

Then instruct the groups of pupils in their tasks:
NOTE: If compasses are not available remember gravestones are traditionally erected with their long axes aligned north – south, and lettered on the eastern side. However, many square monuments have faces and lettering on four sides, allowing a wider range of measurements to be made. The use of a qualitative weathering scale has been suggested (for details see **BAR9 teachers' notes**) to help pupils decide the amount of weathering. The potential for error in using a subjective scale should be discussed during the interpretation of results. Suggested copies of worksheets can be found in document **BAR8 pupil worksheets**.

Hypothesis 1: Did the type of stone used to make monuments in this churchyard vary over time?
Pupils should survey the gravestones and monuments in their allotted section of the churchyard, and record on worksheet 1 the kind of stone used against the date for each gravestone.

Hypothesis 2: Does amount of weathering that has occurred vary with the type of stone used?
Pupils should make an estimate of the weathering of selected gravestones using the 4 point subjective scale provided on the worksheet. Log the results against rock type on worksheet 2.

Hypothesis 3: Does the rate of weathering of marble vary with the direction the marble surface is facing?
On a marble monument, with lead letters that were once hammered flush with the surface but are now standing proud, a tyre depth gauge can be used to measure in millimetres the thickness of marble weathered away over the elapsed years. (See **Figure 2**) Although many stones are facing east, some square memorials provide opportunities for north, east, west and south facing measurements. A rate per year can be calculated for faces with different aspect (direction of facing) and recorded on worksheet 3.

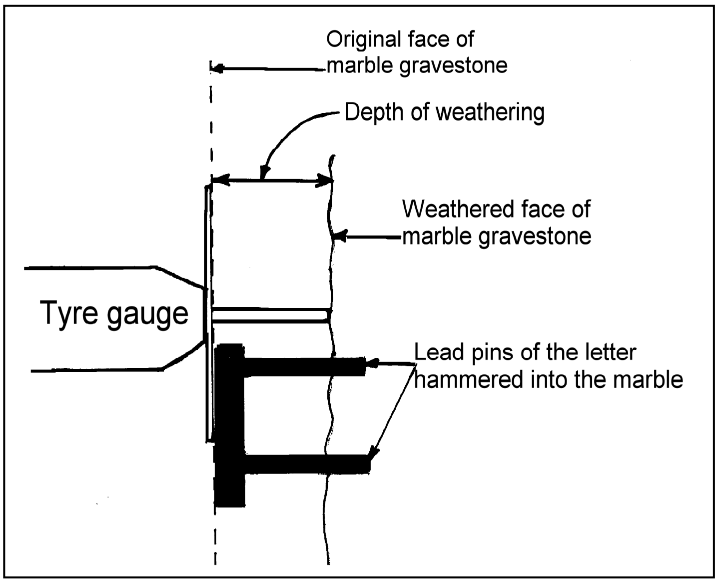

Figure 2. Section to show measurement of weathered marble face.

TASK 2: Identifying gravestones made from metamorphic and igneous rock.
Ask pupils to identify an igneous and metamorphic stone, and produce either a sketch or digital photograph to illustrate their description of the rock and their conclusion as to rock type. [Worksheet 3 in **BAR8 KS3 worksheets**.]

SUMMARY
The onsite preliminary discussion of the results should emphasise the interaction of many variables involved in the weathering hypotheses they have been investigating. More detailed work can be done in the laboratory as a follow–up activity. Apart from rock type and aspect there are other variables which might influence the weathering e.g. the amount of moss, the shading due to closeness to a wall, or building, or a tree; being higher up a slope and more exposed, or lower down, etc. The use of subjective and objective methods of data collection could also be discussed.

Figure 3. St Mark's Church and church gate.

Site 2: St Mark's Church Gate.

Task 3: Identifying The Rock Features In The Church Gate.
Ask pupils to describe and identify the rock type in the gateway at the entrance to St Marks on Vicarage Lane. Observations should be recorded on the sketch on worksheet 4. Pupils should be asked to:

* Describe and identify the rock type used in the construction;
* Look closely at the individual stone blocks marked on the sketch and for each one that has been lettered, sketch in the bedding structures;
* Mark an arrow showing the current direction in block "**c**" and;
* Look closely at block "**a**" and decide if it has been placed in the wall upside down.

Task 4: **Describe the weathering on the church.** Inspect the front of the church and sketch and describe examples of weathering you can see. Does it look like the same stone as in the wall? (Use worksheet 5)

☛ At the completion of these tasks, assemble the group close to the church gate, just inside the churchyard. Use the following questions to prompt discussion of the issues. Indicate that this is a preliminary discussion. The follow up to this visit, in the laboratory, will involve combining all the results for presentation and discussion of the hypotheses.

Sites 1 & 2 Summary Discussion.

Possible questions/tasks	**Possible answers**
What was the most common rock type used for gravestones, and what was the least common?	Igneous most common, sedimentary least common. Ceramic and brick structures may reflect proximity to the Potteries.
Which rock type seems to have been weathered the most?	Most of the local sedimentary rocks are easily weathered e.g. the few red sandstone monuments from the 1850s, or are very weak clays and were therefore not used. (However, notice the brick and ceramic monuments which have used fired clay: a man-made metamorphism!). Also point out that many stones are from the mid twentieth century, and haven't had much time for weathering to affect them.
Which side of the gravestone seem to be weathered most? (The inscriptions are usually on the eastern side)	Usually, where weathering is discernable, it is often the western side, facing the prevailing winds and rain.
Apart from rock type, what other variables might have affected the amount of weathering of these gravestones?	Exposure to, or shelter from, the rain, frost and wind. A location where the stones remain damp, e.g. under a tree, on the north side of a building.

The stone in the wall and gatehouse for the church is a sandstone. What possible reasons might there be for so few gravestones made from this rock?	There are several possible reasons: the quarry closed after the church was built (i.e. the resource was exhausted); the sandstone wasn't as attractive as some of the igneous rocks (i.e. a choice on aesthetic characteristics); or the sandstone only broke into blocks, not large flat slabs (i.e. the jointing made the sandstone unsuitable) **NOTE:** The rock is known locally as "Gornal Grit". It is a Silurian sandstone which outcrops two kilometres to the north of Barrow Hill, and is no longer quarried.
What signs of weathering can you see on the church building frontage? Why might the church builders have used tiles at the entrance to the church instead of stone?	Signs of weathering along the less resistant bedding structures in the stones. The tile entrance area may have been done for decoration, but also the tiles might have been thought to be more hard-wearing than the local stone. (Firing clay could be described as man-made metamorphism).

☛ Move the group through the gate and left along Vicarage Lane towards Barrow Hill. Draw the attention of the party to the wall on the left and its changing nature as they get further from the church. The walk and the work at Site 3 should take about 20 minutes.

Site 3. Vicarage wall study.

Near the northern end of the wall (see **Figure 1**) invite the group to inspect the wall and to comment on the differences from further south. Record observations on worksheet 6.

Possible questions/tasks	**Possible answers**
What differences can you see in the SHAPE of the stones in the wall here?	They are uneven and irregular, fitting together with the aid of cement.
What differences can you see in the TYPE of stones used in the wall here?	Here is a much greater variety: uneven sandstone blocks, concrete, blue-grey slag (with "bubbles") and blue-grey dolerite (without "bubbles"), etc.
Why do you think these materials were used in the wall here?	Reducing the costs of building (or re-building) the wall. Un-dressed, and uneven pieces of locally available material that are cheap to obtain.
What do you notice about this boundary line as you trace it further north?	Further north the wall is replaced by metal railings, an even cheaper, twentieth century solution, when labour became expensive.

Task 5: Describe the wall and the material in its construction.

☛ Continue north along the path and down the steps. Take care as these steps become slippery when wet. After the foot of the steps, continue for about 40 metres, and then take the first small path to the right. After 20 metres the path again forks. Take the left turn for about another 20 metres. The space at the foot of the quarry face is limited to the footpath. Ask the group to look at the face to the left (west). Observations may be recorded on worksheet 6. The walk and the observations here should take about 40 minutes.

Site 4. Barrow Hill Quarry.

Possible questions/tasks	Possible answers
Look at the (western) face, and describe the rock.	The rock is black and strongly jointed vertically. It has no layering or bedding.
Do you think this rock is likely to be igneous, metamorphic or sedimentary?	It is likely to be igneous as it has strong vertical jointing. It has no obvious bedding or cleavage so is less likely to be sedimentary or metamorphic. (So additional information is needed).
There are loose fragments of the rock lying on the scree slope. How did they get there?	Either by physical weathering and falling under gravity from the face, or left-over from quarrying work.
Carefully break open one or two pieces lying loose on the scree, whilst wearing protective goggles and using a GEOLOGY hammer (made of metal that will not fragment). Pass the broken pieces around and ask pupils to describe what they see.	The outer few millimetres are badly affected by chemical weathering, but the interior shows dark, medium-grained crystals: i.e. dolerite. This is the final confirmation that the rock is igneous. **NOTE**: Some fragments may show small "lumps" of baked Etruria Marl, which were incorporated into the hot magma whilst still wet and broken up by explosive steam and gasses.
Pick up a loose piece of the rock from the scree, and pour a small amount of water onto its surface. Ask pupils what they see and what they deduce about its porosity.	The water does not sink into the rock, therefore it is not porous (i.e. no pore spaces). This is consistent with it being a crystalline igneous rock. **NOTE:** This does not necessarily stop the dolerite being permeable (i.e. able to let water through), since water may penetrate the vertical joints.
If this is a medium-grained igneous rock, what does that tell us about its rate of cooling and method of formation?	It cooled fairly slowly, and so was not a lava. It crystallised as a magma, under ground.
On close inspection the jointing can be seen to form vertical hexagonal columns. What does this tell us about the cooling of the magma?	Regular and even hexagonal columnar jointing is formed when an igneous rock solidifies, and continues to cool and shrinks evenly between two roughly parallel cooling surfaces. This is further confirmation that the rock is igneous (and the cooling surfaces were roughly horizontal).
Which is the younger rock: the dolerite, or the rocks into which it is intruded?	**Principle of Cross Cutting Relationships**. The dolerite cuts the sedimentary rocks (Etruria Marl), and so must be younger.
What was it about the dolerite that made people want to quarry it? Do you think it would have been used as a building stone	They wanted the rock because it was physically and chemically resistant. It was broken up and used as a road stone, or aggregate. It is unlikely to be used much as a building stone as it breaks into irregularly shaped pieces.

Task 6: Describe the evidence for this being an igneous rock. (Use pupil worksheet 6)

Task 7: Sketch the western quarry face and label it. (Use pupil worksheet 7)

☛ Ask the group to turn around and look at the eastern face behind them.

Possible questions/tasks	Possible answers
What difference can you see between the eastern and western faces?	The eastern face is dominantly of a black rock, but not clearly jointed.
Assure the group that this is the same dolerite. What does the lack of columnar jointing tell you about the cooling of the rock on the east side of the quarry?	That the rock did not cool evenly. This may well be due to the presence of quite large lumps of wet Etruria Marl, (xenoliths) caught up by the molten magma creating uneven cooling gradients through the magma. Midway along this eastern face, at the top of the scree is a yellowish area of rock, which marks the contact between a reddish baked xenolith and the dolerite affected by the heated vapours from the magma. (Scrambling up the scree to see it is inadvisable).

☛ Leave the quarry by the same route and return southwards towards St Mark's church. At the top of the steps there are two routes to the summit of Barrow Hill. (See **Figure 1**) The first route is to turn left and proceed along the small footpath, which has steep slopes to the north of the path, up to the cross at the summit. The second route, avoiding the risk of the top of the steep slope is to continue to the gate at the top of Vicarage Lane, and then turn left and proceed up the stepped footpath to the large cross visible at the summit of the hill. (See **Figure 1**). The walk and the observations at the summit should take about 40 minutes.
Just north of the cross there are steep slopes and no paths: keep the party on the south side of the summit.

Site 5. The summit of Barrow Hill.

Possible questions/tasks	**Possible answers**
Look at the metal cross. What do you notice about the surface (apart from the graffiti)?	It has an interlocking, coarsely crystalline structure and no pore spaces. It cooled slowly from an iron rich melt in a furnace. **NOTE:** Draw a loose comparison with a natural igneous rock like dolerite, which, unlike the steel is made of several different minerals.
Why was the steel used for the monument?	It is more resistant to weathering: the material is chemically stable, and being non porous, it is resistant to physical attack by frost and water.
Looking at the slope you have just walked up (or along), where would you predict that the more resistant and less resistant rocks are to be found below the soil?	The more resistant rocks (dolerite) would be found under the higher ground, whilst the less resistant rocks, being more easily eroded, would form the lower slopes.
Look at the skyline (if it's a clear day), and ask pupils where they think they can see more resistant rocks on the horizon. See the "**Barrow Hill: Dudley Volcano**" leaflet from Dudley Museum (Tel: 01384 825575) for a useful profile of the horizon.	It is the hills that will be formed by more resistant rock, which have not yet weathered down to the level of the less resistant rocks. From the west, working clockwise to north: **The Clee Hills; The Long Mynd;** from the east, working round to the south: **Rowley Hills and Clent Hills**: towards the west: **Abberley Hills**.
Draw the attention of the group to the small patches of weathered dark rock visible in the soil at the western edge of the cross. Ask them if they can see the contact between the more and less resistant rocks.	The precise contact is not actually visible, but it can be closely inferred to within several centimetres. You are standing on a NE-SW trending fault between the less resistant Etruria Marl (down-slope, behind you) and the more resistant Barrow Hill Dolerite which is exposed beside the cross. (See **Figure 2** in **BAR4 briefing**)
Point down into the quarry to the northwest from which they have just walked and remind them this is the same igneous dolerite exposure they saw there. Underground igneous rocks can feed surface eruptions. Ask the group where they think any volcano linked to this dolerite, might have been?	The dolerite was emplaced underground, below the volcano. (i.e. the volcano was perhaps 1000m vertically above your position). All of the surface volcanic features, like cones and lavas, have been eroded away. Only the pieces down-faulted have not yet been destroyed by erosion.
Ask the group what forces might have propelled the (hot liquid) magma so far upwards through the rock – against the pull of gravity.	Eruptions are driven by density differences between the hot liquid magma (less dense) and the fractures in the cold rock (more dense) into which it is intruded. The vertical intrusion stops at the level where the two densities are the same, or when it erupts at the surface (as a lava). Draw a simple analogy with water and less dense oil. Less dense oil moves upwards through the denser water until it reaches the surface. (Or remind them of the "volcano in the laboratory" demonstration from their preparation work).
What forces of weathering and erosion might have reduced this 1km thickness of rock down to the present land surface?	Physical and chemical weathering. Erosion by rivers and mass wasting (slow motion creep down the hillsides especially after rain). [Glaciers during the Quaternary (i.e. the last 2 million years) covered the area, but there is little visible evidence of glaciation here.]

Today, if humans don't intervene, where might the rock weathering products moving west from this area be deposited?	Any material moving west or south west might be picked up eventually by the river Severn, and carried the 90 kilometres or so to the Bristol Channel (and then possibly into the east Atlantic Ocean) and deposited to form new sedimentary rocks in a new Rock Cycle.
If a geologist in millions of years' time was able to study these rocks forming today what "fossils" might be found in them?	Apart from marine organisms with bony or shelly parts, there might also be human debris, such as hulls of sunken ships, plastic bags, beer cans, ipods, etc. Emphasise the importance of more resistant elements to increase the chances of fossilisation: so no jelly fish, or paper, for example.
Draw the attention of pupils to the housing estate to the south east. What are the different parts of the housing estate made from? Where did all of the materials come from?	**Bricks:** from clay, fired in a kiln to make it more physically resistant: **Cement** from limestone, gypsum and sand mixed with water: **glass** from sand, fired to make it liquid and then rapidly cooled: **roof tiles**, likewise; (slates are natural rocks, but there aren't any used here); anhydrite for the **plasterboard**; metals for **TV aerials, wires, door handles** etc, are from metal ores; **roads** are tarmac made from oil products (mixed with rock fragments called aggregate, to make it wear better) as are **plastics**. The **soil** in the gardens is weathered from the local rock. The concrete making the **hospital** is made from limestone, clay and anhydrite, all quarried from the ground. Even the **wood and plants**, grew in soil weathered from rocks.
Try to estimate the combined size of the hole that is produced in obtaining the materials to build one housing estate.	This is certainly unquantifiable in the time you have. Stay with "enormous", and "No, much bigger than that!" and, "No, much bigger!"

Task 8: Summarise their observations about the landscape & housing. (Use pupil worksheet 8)

☛ Return down the steps to the vehicle park, by St Mark's Church.