Introduction.
In order to get a more complete picture than is possible whilst at Site 1, results from all of the groups could be combined as a follow–up activity, perhaps using spreadsheets to create the graphed results. The larger sample can be used in a more detailed interpretation of the results than is possible with raw data from each workgroup. The suggested exercises relating to hypotheses 2 and 3 allow for a discussion about sources of error in scientific investigation; objective methods with instrument and operator errors; and more subjective methods with errors related to individual perception, interpretation and bias.

Task 1: Testing Hypotheses.
Hypothesis 1: Did the type of stone used to make monuments in this churchyard vary over time?
The table below is based on a small sample from areas 1 and 2 in the churchyard.

	Sedimentary	Igneous	Metamorphic	Ceramic & Brick	Mixed (more than 1 material)
Before 1860	1	0	0	0	0
1860 to 1910	1	1	1	0	0
1911 to 1930	0	0	5	0	1
1931 to 1950	0	15	1	2 (+1 with no date?)	0
1951 to 1970	0	4	0	0	0
1971 to 1990	0	0	0	0	0
1991 to present day	0	1	0	0	0
TOTALS	2	21	7	3	1

Summarise:

Which rock type is most common overall? IGNEOUS

During which period were sedimentary rocks more common? PRE 1860

During which period were igneous rocks more common? 1931 TO 1950

During which period were metamorphic rocks more common? 1911 TO 1930 (MAINLY MARBLE)

Can you interpret your results?
Early burials used local stone possibly due to the high cost of transport before transport by rail became widespread. Attractive (and hard wearing) igneous stones from abroad became available at an acceptable price after the war. The ceramic memorials became a traditional feature in Black Country churchyards. The materials and skills were locally available, and the product durable after firing.

Hypothesis 2: Does the amount of weathering that has occurred vary with the type of stone used?
[Pupils should use a compass to establish the aspect (direction of facing) of the stone. Another simple way is to use the church, which is aligned east – west, with the main door facing south.]

Although the character of different rock types, (such as chemical composition, porosity, the presence of jointing and bedding planes, the resistance and amount of cement holding sedimentary grains together, etc.) do influence the rapidity of weathering, this simple picture is complicated by other variables. For example, local factors encouraging weathering such as exposure to wind and frost, shading from the drying/warming effects of the sun, growth of lichens and moss on the stone; the length of time exposed to weathering. The most clear cut result at this site is likely to be that the west facing side of old porous sedimentary stones with weak cement, show the most weathering damage.

Figure 1. Lead letters on a marble headstone. (Family name deleted)

On other rocks a simple way of estimating weathering is to use a subjective five point scale, as below.

0: smooth original surface.	(Unweathered)
1: pitted original surface.	(Slightly weathered)
2: lettering showing signs of being weathered.	(Weathered)
3: lettering very hard to read.	(Well weathered)
4: original surface almost completely destroyed.	(Severely weathered)

Figure 2. Igneous stone "0" on the scale.

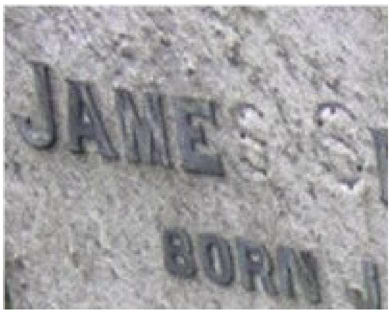
Figure 3. Metamorphic stone "2" on the scale.

Figure 4. Sedimentary stone "3" on the scale

Figure 5. Sedimentary stone "4" on the scale.

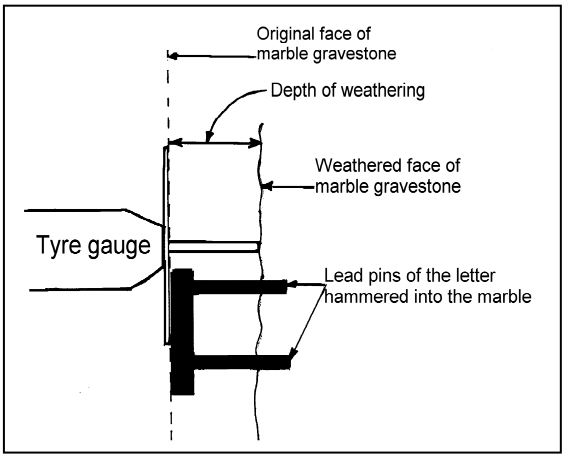
The precise results of this subjective weathering survey will vary, depending on the sample of memorials examined. However, in general, faces open to the prevailing wind and rain (usually westerlies); faces sheltered from the drying action of the sun by buildings or vegetation; stones which are more porous (sandstones), or made of calcium carbonate (marble and limestones), show the most weathering. Emphasise the role of water and frost in these processes of physical and chemical weathering, not forgetting the effects of biological weathering.

Hypothesis 3: Does the rate of weathering of marble vary with the direction the marble surface is facing?



Weathering rates can be measured directly on Marble stones, using a tyre depth gauge. When fresh the lead letters are hammered flush with the face of the stone. (See **Figure 6,** where the holes for the pins on the missing letters can clearly be seen.).

Figure 6. Lead lettering on head stones



Over the years the marble chemically weathers back, leaving the letters standing proud. This distance can easily be measured with a tyre gauge and divided by the number of years the stone has been exposed, to get a rate in mm / yr. (**See Figure 7**).
Since marble weathers chemically, different amounts or rates of weathering might be expected to vary to the exposure to acidic rainwater.
Again the discussion of the results should highlight the other variables, apart from aspect, that will influence the rate of weathering of these stones.

Figure 7. Section to show measurement of weathering on marble headstones

TASK 2: Identify metamorphic and igneous rocks used as headstones.

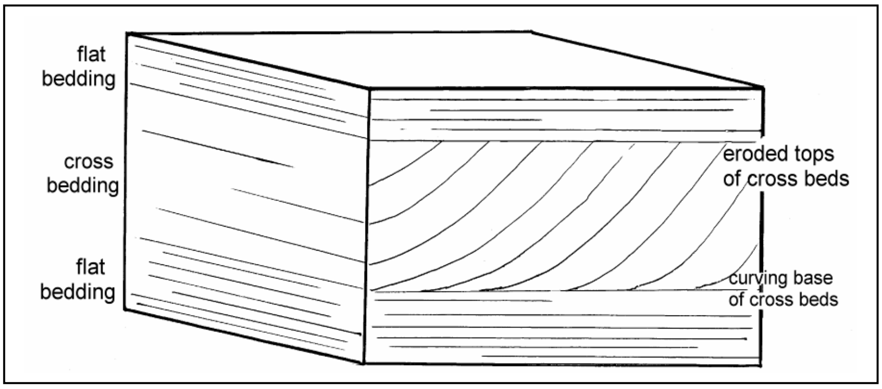
The groups may need assistance confirming the reactivity of marble to dilute HCl. This test should be discretely used on the back of the monument, and the site washed with water afterwards. [There is no real need to search for the few sedimentary headstones as the church gate exercise provides an opportunity to look closely at sandstone.]

Site 2. St Mark's Church gate

Task 3.
For this exercise pupils can only see the front face of the individual blocks. Point out that in Earth Science it is always best to try to see things in three dimensions, but that it isn't possible here. As a result some of the "flat bedded" structures may actually be cross bedded, only **appearing** to be flat, but in fact be sloping upwards inside the block, where we can't see it. (See **Figures 9 & 10**)
Ask pupils to work with the information they can see at the front of the block.

Figure 8. St Mark's Church and gate

Figure 9. A block with flat bedding and cross bedding.



The significance of the "upside down" block "a" in this task is related to the importance of the **Principle of Superposition,** which states that younger rocks lie on top of older rocks, and allows beds to be placed in their correct sequence, with the oldest first. This principle breaks down of course if the rocks are upside down. Earth scientists need to know if they are dealing with inverted beds (they are more common than you might think – but not in the West Midlands). There are many such "way up" criteria, but cross bedding is a useful one, and can be seen in very many stone buildings and walls. (See **Figure 10**).

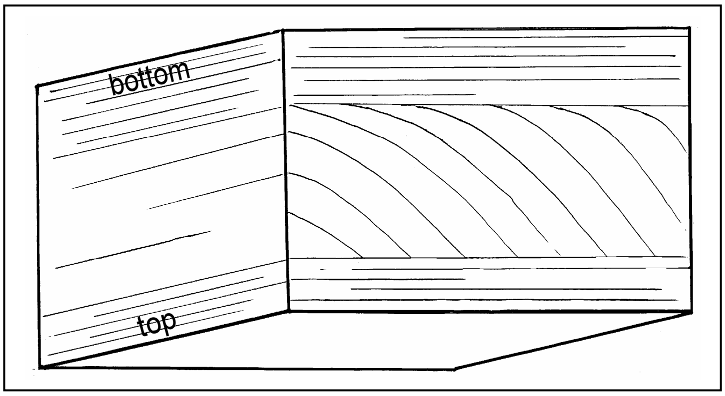


Figure 10. Inverted block showing cross bedding.

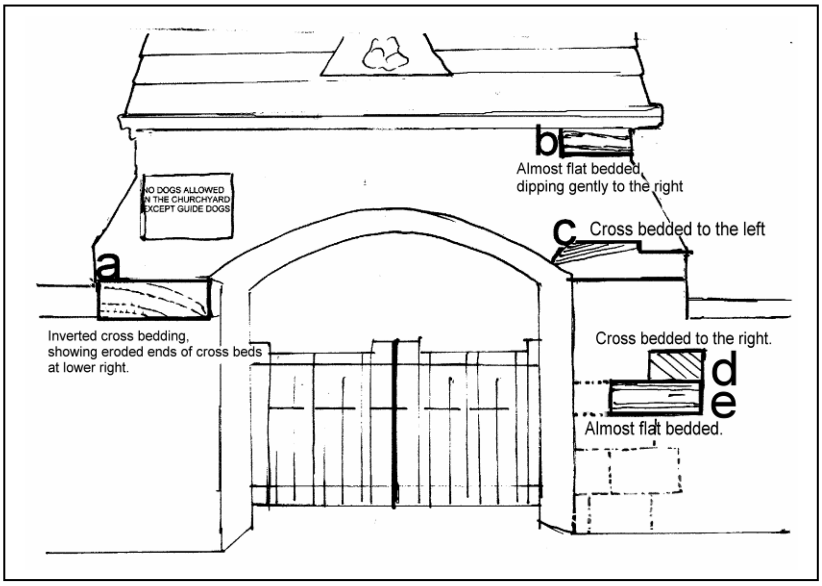


Figure 11. Study of St Mark's Church gate.

Task 3. Description of rock type used for the church gate:
Medium grained, well cemented together except for a few layers. Shows bedding and cross bedding. No fossils. It is a sedimentary rock.

Name of rock type used for church gate: It is a sandstone

The blocks with bedding best described as flat bedding are:
b, and e

The blocks with bedding best described as cross bedding are:
a, c, and d

Is block "a" upside down? Yes. Now explain your answer:

Yes it is upside down.
The eroded upper edges of the cross beds are at the lower right corner of the block, therefore it is upside down.
At the top left the cross beds can be seen to be curving over to be nearly parallel to the top of the block. This indicates the bottom of the cross bed, again showing it is upside down.

Task 4. Study of Weathering on St Mark's Church.

The stone used for the church is the same Silurian sandstone ("Gornal Grit") as in the church gate and wall. It shows weathering in much the same way picking out the less resistant layers. The roof is made of Welsh slate, with some locally fired tiles

The approach to the church door is a decorative and hard wearing pattern of locally fired tiles and bricks. (See **Figure 12**).

Figure 12. The tiled approach to St Mark's Church door.

Site 3. Study of the vicarage wall
To the north of the vicarage, the boundary wall changes in character, revealing something of its constructional history. At this point it looks very much like a rebuilt structure. (See **Figure 1** in **BAR7 Field exercises**). To the north of the last pillar of sandstone made of well cut and dressed blocks the wall material becomes much more varied. The base is more suitable regular sandstone blocks, but the upper part contains more irregular and varied material, including sandstone, dolerite (probably from the quarries to the north) and fragments of furnace slag (the pieces containing gas bubbles).

Task 5. Describe the materials and construction of the wall
After asking pupils to identify some of the material, the discussion could usefully go on to the costs of building and maintaining stone walls. This should include costs of materials, their transport and the labour to build the wall. More resistant, regularly dressed (shaped) blocks, moved from a more distant quarry, would be more expensive, than less suitable, but available "lumps" of material. (See **Figures 13 & 14** below)

Figure 13. North section of the vicarage wall

Figure 14. Detail from the wall.

Site 4. Barrow Hill Quarry

Task 6. Summarise the evidence that the rock exposed here is igneous.
(Use pupil worksheet).

What is the evidence that this rock is Igneous? (Use the headings to help)

Jointing: Hexagonal jointing is formed when molten rock crystalises and contracts, forming an even pattern of stresses through the rock

Bedding: There is no bedding or layering in this outcrop.

Metamorphism: Where it is in contact with the Marl it has baked it. This is contact metamorphism, and is caused by hot magmas.

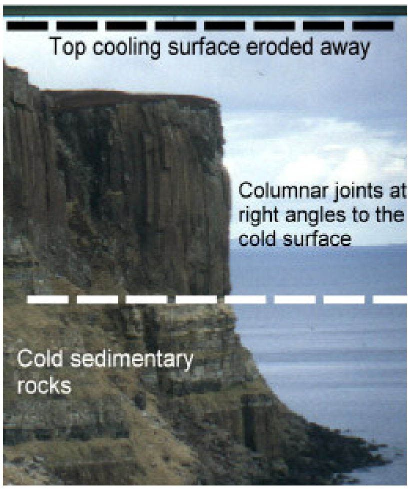
Crystals: medium grained interlocking crystals

What use was the rock from this quarry used for? Roadstone (originally for nineteenth century turnpikes) It is more resistant to weathering and is physically strong enough in usage to take the load. It breaks too unevenly to be a building stone.

The western face of the quarry shows a dark rock, broken by regular vertical joints and no sign of layering or bedding. This is the first evidence of igneous rock. Breaking open fragments of rock at the foot of the slope (**use a standard geology hammer, made from soft metal which will not fragment dangerously in use**) will reveal several millimetres of weathered rock around an interior with medium grained, interlocking dark blue crystals. This is the final evidence of igneous rock, indicating a medium rate of cooling in an underground magmatic body. The rock is a dolerite, and it is not porous, although it may well be permeable to water passing down the vertical joints. You may find that some parts of the exposure show very fine grained crystals where the magma cooled more quickly against the cooler sedimentary rocks and technically could be called basalt, but there are no extrusive rocks here.

The reason for this early quarrying activity was the need in the early 1800s for material to surface the new turnpikes, two of which passed very close to the north, and south of Barrow Hill. One ran from Dudley to Himley, whilst the other ran from Dudley to Kingswinton, now respectively the B4176 and the A4101. The rock is resistant both physically and chemically, and breaks into small irregular pieces, making it unsuitable for building stone, but useful as roadstone.

The vertical joints are the side view of hexagonal columnar joints formed when the hot magma continued to cool after becoming solid rock. Where the cooling is even, the stresses create regular hexagonal columns at right angles to the cooling surface, which in this case must have been close to the horizontal. A clearer example can be seen in **Figure 15**.



When the cooling surfaces are vertical, as in a dyke, the cooling joints are horizontal. Due to the depth of erosion it is difficult to be sure of the precise shape of the Barrow Hill dolerite, although the lower surface seems to be close to the horizontal, and in a 1945 study was observed almost parallel to the bedding.

Figure 15. Hexagonal columnar jointing in dolerite: Skye, Scotland.

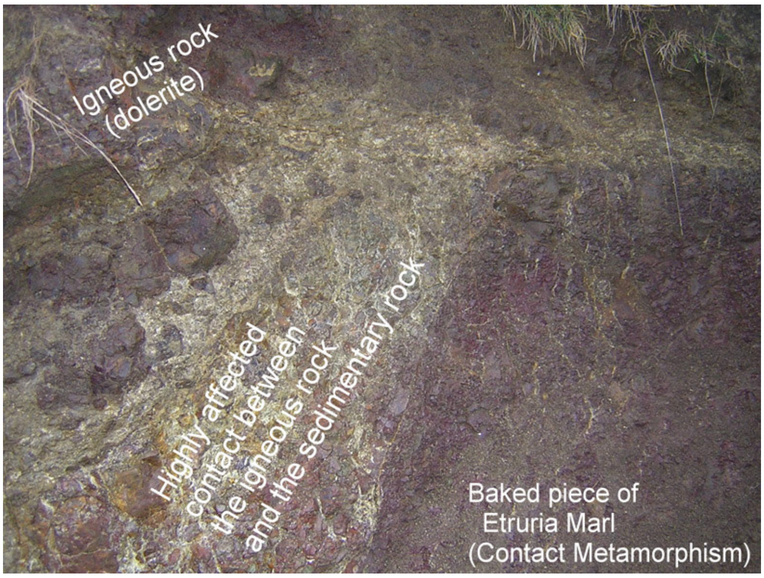


Figure 16. The magma – Etruria Marl contact showing metamorphism.

Draw pupils' attention to the eastern face, above the scree slope and ask about the differences that can be seen. The key difference is the absence of regular jointing, implying an **uneven** set of cooling stresses. This was probably caused by large lumps of cold and wet Etruria Marl being caught up by the hot liquid magma. One report from the 1940s suggests there are three quite large "lumps" (called xenoliths) in this face. Unfortunately, they are not now visible. However, one example of such a xenolith can be seen half way along the face, but not very clearly. It is advised that groups do **not** clamber up the scree to view this closely. This xenolith has been extensively baked, and turned red by the heat of the magma, and is an example of contact metamorphism. (See **Figure 16**)

Task 7. Sketch the west face and infer the orientation of the cooling surfaces. (Use pupil worksheet 7.)

Figure 17. Hexagonal columnar jointing in the west face: Barrow Hill Quarry.

Site 5. Barrow Hill summit.

Task 8: A summary of the view from Barrow Hill summit.

What hill areas can you see? Explain why these areas are hills.	Depending on the visibility: **The Clee Hills; The Long Mynd; Rowley Hills and Clent Hills**; **Abberley Hills**. The hills indicate more chemically and physically resistant rocks, and will take longer to weather down to the level of the less resistant rocks.
What will eventually happen to the rocks being eroded and transported to the west of Barrow Hill?	Weathering erosion by slipping and slumping on slopes and rain wash will move material down slope to the rivers. To the west flows the river Severn, and it will carry its load to the Bristol Channel and then into the eastern Atlantic Ocean to form new sedimentary rocks as part of 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 allow fossilisation: so no jelly fish or paper, for example.
Look at the housing estate to the SE. What materials have been used to make it? Where did these materials come from?	**House Roofs:** Tiles from clay fired in a kiln. The clay is dug from the ground like slates which are natural stones, not man made. There are no slates on this housing estate. **House walls (inside and out)**: Bricks from clay fired in a kiln. Inside will be plaster board made from gypsum or anhydrite. **Cement & concrete:** sand, limestone, gypsum. Also clay and aggregate (stone fragments) **Windows:** Pure silica sand, melted and cooled rapidly to a glass. **Gas/oil for central heating:** Drilled from oil traps and piped in. These fuels represent fossilised energy, created by organisms from sunlight, millions of years ago **Roads and driveways**: petroleum (oil) products like tarmac, mixed with stone fragments. **TV aerials, wires, garage doors, and cars:** Metals smelted from metal ores. **Garden Soil:** Formed when feldspars are chemically weathered to form clays. Soils are mixtures of naturally weathered products including sand and clay, plus some organic material. **Grass and trees:** Grow in soil. (Also use gasses from the atmosphere and sunlight). All of these products have their origins in the ground, either quarried or mined, or are growing in it.