Introduction.

☛ Individual groups will need 10x hand lenses, measuring tapes, compasses and clinometers if dip measurements are to be attempted, as well as clipboards, pencils, rulers and copies of the relevant field sheets for individual pupils. (See **KNO8 worksheets**).
Group Leaders will need a plastic bottle of dilute HCl, a small plastic bottle of water. A digital camera will also be useful.

☛ Apart from the theme of human use of geological materials, the main theme here is that of the **Principle of Uniformitarianism,** using present day processes to help us interpret ancient rock cycles. Field leaders should have decided which combination of the following exercises the groups are to tackle before they arrive on site. Since there are no toilet facilities on Wenlock Edge parties are advised to stop in Much Wenlock, perhaps making use of **worksheet 2** in the process, and making a visit to the museum.

1. Bus quiz: for the journey from The Ercall (for those groups linking the two sites).
2. Much Wenlock Building Stones.
3. Landscape: Ape Dale and Wenlock Edge.
4. Knowle Quarry south.
5. Knolwe Quarry (west).
6. Knowle Quarry Lime Kilns.
7. Jack Mytton Way. Comparing The Rocks with The Ercall (*for those linking the sites).
8. Lea Quarry Viewpoint.

It is possible to extend this ESO-S visit locally by contacting the National trust, at Cardingmill Valley, or Bardon Aggregates at the nearby Lea Quarry. See **KNO3 Locaccess** for details.

☛ From junction 6 on the M54 turn south along the A5223 to the junction with the A4169. Turn right and follow the road downhill into the Severn valley. Before reaching Buildwas take the left turn towards Much Wenlock, still following the A4169 into Much Wenlock.

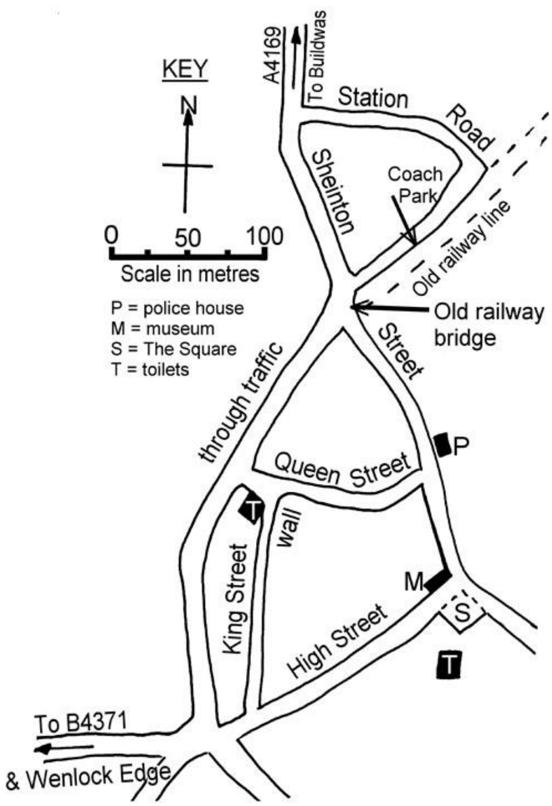

Figure 1. Map of Much Wenlock.

☛ Much Wenlock is an optional site on this itinerary. Group leaders may want to include a stop here to take advantage of the toilet facilities that are not available along Wenlock Edge. This may be combined with a worksheet exercise on the building materials used in the town. (See **worksheet 2** in **KNO8 worksheets).**

The coach park is on Station Road, which is signposted as a left turn from the A4169 when approaching Much Wenlock from Buildwas. The closest public conveniences are on the junction of King Street and Queen Street. The best route is to turn left at the end of Station Road and walk along Sheinton Street, turning right along Queen Street. An extension could be made along King Street, turning right along High Street and then left into Sheinton Street at the Square. Pavements are often narrow or absent, so care should be taken to look out for traffic.

[Groups who want to see the museum geological display may simply visit the museum, or arrange a guided visit by contacting the Shropshire Education Officer on **01584 813650**.]

Site 1: Building Stones of Much Wenlock

☛Using **worksheet 2** groups could be asked to observe and record the geological building materials in use in the town, as they walk past. If there are large numbers of people on the streets it will be advisable to subdivide a large group, and supervise them closely when crossing roads.
The bridge abutment at the junction of Station Road and Sheinton Street is an opportunity to see large blocks of limestone in use. It also highlights the building of the rail link which allowed exploitation of the southern Wenlock Edge limestone quarries (including Knowle Quarry) from the 1860s onwards. A range of other building stones is on view in the town, including blocks of local limestone.

Close inspection of the limestone wall at the north end of King Street, exposed to weathering for many years, reveals an excellent range of Silurian fossils, much more clearly than will be seen in the quarries. There is no footpath here and groups will need to be aware of traffic. Remind groups to be considerate of the people who live and work in the town, and of course, not to remove or damage any parts of the walls, or cars parked close by them.

Presthope Car Park (Wenlock Edge)

☛Return to the coach and travel south along the A4169 to the junction with the A458. Turn right onto the A458 and within 500 metres turn left onto the B4371. After 2.25 km the site office of Bardon Aggregate is on the right. A further 1.5 km along the B4271, just before the right turn to Hughley, the Wenlock Edge (Presthope) car park is on the right. This is big enough for a coach, although it is a very tight fit. Do not block the gate to the track from the car park onto Wenlock Edge when parking here.

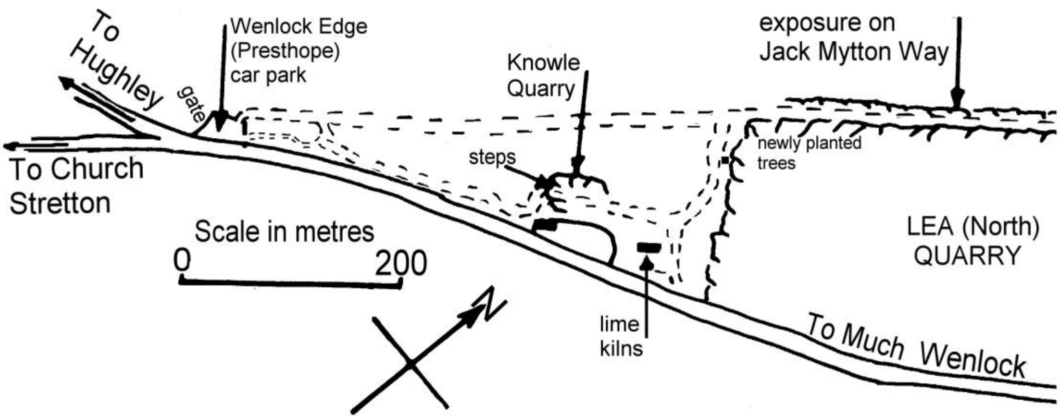

Figure 2. Map of the Knowle Quarry sites

☛ Warn the group that sensible behaviour is required on the footpaths which are along the top of Wenlock Edge, and also become slippery when wet. Lead the group uphill out of the car park and then north eastwards along the footpath on the crest of the scarp slope of Wenlock Edge. After a hundred metres or so the view point to Shrewsbury in the NW is revealed where the trees have been cut back. The landscape here is classic scarp and vale topography, heavily influenced by the geology of dipping, alternating more and less resistant rocks. The first task is to orientate the group and get them thinking about the landscape.

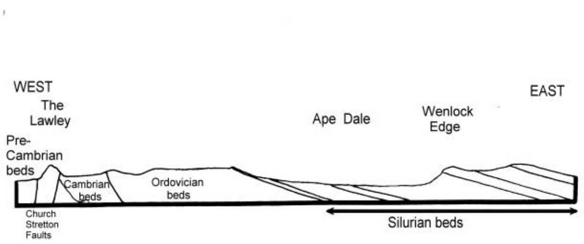

Figure 3. Section across Wenlock Edge.

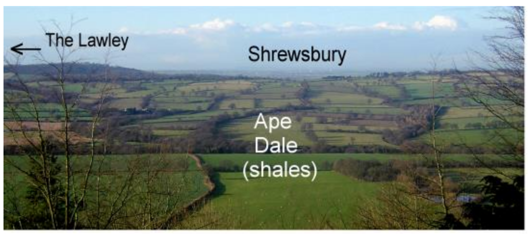

Figure 4. Site 2: Presthope View Point

Suitable questions at this site.	Acceptable responses.
Ask the group to use a compass to establish which direction they are facing.	West.
Using the section on **worksheet 3** ask the group in which direction the beds are dipping?	To the east.
Ask the group to predict what kinds of rock lie below Wenlock Edge.	The beds are layered, a good indicator of sedimentary rocks.
Ask the group to use the **Principle Of Superposition** to work out in which direction the younger beds lie.	To the east (i.e. in the direction of dip in rocks that are not overturned.).
Ask the name of the ridge on which they are standing.	Wenlock Edge.
Ask the group the name of the valley in front of them.	Ape Dale.
Ask the group to explain why the land in the valley is lower than on the ridge.	Hills are formed by more resistant rocks, whilst less resistant rocks are eroded to lower levels. Ape Dale runs north–south along a less resistant bed of shales.
Ask the group why Ape Dale has a steeper side and a more gently sloping side.	The western slope is the dip slope of the beds below, whilst the steeper eastern slope is undercut into softer shales protected on top by more resistant rocks.
Summarise the predictions the group have made about the rocks beneath their feet. They are sedimentary, they are dipping eastwards, and they are more resistant to weathering.	

☛ Those groups who have previously completed the ESO-S site at The Ercall may want to extend this part of the visit by placing the two sites in a geological context.

Suitable questions at this site.	Acceptable responses.
What age were the rocks we saw at the Ercall?	(Precambrian volcanics) and Cambrian sandstones.
Using the section on the worksheet are the beds here older or younger than the beds at the Ercall?	Younger (because they are on top – **The Principle of Superposition**). These are Silurian in age, about 420 million years as opposed to the 540 million years of the sandstones at The Ercall.
What do you notice about the beds between the Cambrian and the Silurian?	They are all marine beds, with periods of erosion (called unconformities). This area was a shelf sea on the edge of an oceanic area to the north west. No continental deposits are formed here till the Devonian period. See **KNO4 ES briefing** for details).
Point out that the 130 million year gap between the two sites is represented here by the thickness of rocks between Wenlock Edge and outcrops to the west like The Lawley.	

☛ Take the group on the path away from the ridge top, a right fork, along the **Lime Kiln Walk**. The wide and surfaced path, suitable for wheelchairs, then gives way to a narrow track, off to the left, parallel to the road. After 200 metres the path descends a flight of wooden steps into Knowle Quarry. These steps can become very slippery when wet, so descend with care. At the bottom of the steps turn immediately right to find the southern face of the quarry. This is **Site 3**. It is owned by The National Trust and is a protected site. There is no need to damage the face, as specimens may be found along the foot of the face. Please **do not** remove them from here, as opportunities for some collecting occur later.

Figure 5. Site 3: Knowle Quarry (South).

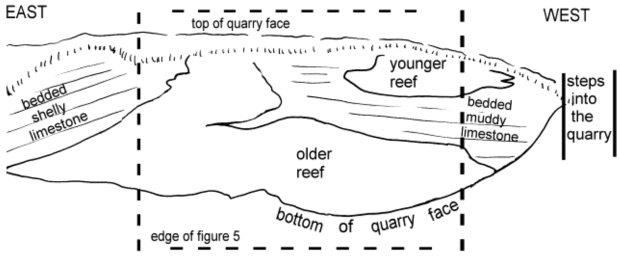

Figure 6. Sketch of main features at Site 3.

☛ First focus attention of the rock type and the evidence it contains of the conditions at the time of deposition (about 420 million years ago).

Suitable questions at this site.	**Acceptable responses.**
Remind the group of their prediction at **site 2** and ask them to look closely and describe the features of the rock in the face.	The rock shows bedding, in places. It contains shelly fossil fragments. It also reacts with dilute HCl. It is a sedimentary rock: a limestone.
Ask the group to inspect the bedded parts of the face to the right and then to the left of the large un-bedded part in the centre of the face. What differences can they see?	The beds to the left are coarser grained with shelly fragments. The beds to the right are finer grained and contain more mud.
Ask the group what might have caused the differences they have found?	The coarser beds were laid down in a stronger current (wave action) whilst the finer grained ones were laid down in quieter conditions.
What might have caused these differences in current strength in places so close together?	The reef may have sheltered the beds to the right from wave and current action.
Measure bedding plane dip on the left of the face. Use a clipboard as a convenient extension of the bedding to create a surface to measure.	18^0 to the SE (160^0 from north)
Tell the group that the large un-bedded "ballstones" are reefs of fossilised coral and other marine animals, and ask "In what kind of environment the rock must have formed?"	Today shelly reefs form in warm shallow seas. (**Principle of Uniformitariansim**). [Point out that they grew upwards from the base at the same time as the bedded layers were deposited next to them.]
Ask the group how many "ballstone" reefs they can see in the face. (Point out that the reefs grew up from the bottom.)	Two
Ask the group if the two reefs are exactly the same age, or if one is younger?	The smaller, upper one is younger (**Principle Of Superposition**), although it co-existed with the upper parts of the larger one.
Ask the group to describe what happens to the older (larger) reef as it grew upwards?	It was laterally more extensive in its younger part. The upper part is narrower, continuing to grow after the lower parts.
Reefs are made up of animals that are sensitive to water clarity / muddiness, salinity, depth, and temperature Which of these factors might have been responsible here?	Not depth, temperature or salinity changes, which would have killed all of the reef animals. The muddiness of the limestone might well have overlain and killed off the right hand side of the reef.

Ask the group what these deposits, laid down in a warm shallow tropical sea, are doing in Shropshire?	Plate tectonic forces moving the crust northwards, away from the tropics) since they were deposited.
What else has happened to these beds since they were deposited (below the sea)?	Uplift and tilting.

☛ Draw the group's attention to the area in the centre of the face, labelled point "c" on **Figure 5**.
NOTE: This is a fragile part of the face which should not be damaged. It is a calcite vein infilling a fault plane which runs along the face and just in front of it. The horizontal "scratches" (called slickensides) were caused when one side of the fault slipped (horizontally) past the other and scratched the wall of the calcite vein. (See **Figures 7a and 7b**)

Suitable questions at this site.	**Acceptable responses.**
Point out the veneer of a calcite vein, now stained red by iron oxide, at point "c", (on **worksheet 4**) and tell the group that it infills a fault plane. Ask the group to describe the marks there on the calcite.	Horizontal grooves and ridges.
How might a fault have caused these groves and ridges?	By sliding past the calcite vein.
In what direction did it slide? [It is often suggested that polished fault planes "feel smoother" in the direction of slippage. Suggest members of the group try it].	Clearly it was horizontally, but here it is not clear which side (in this case the "front" or the "back") of the fault moved left and which moved right.
Using the Principle Of Cross Cutting Relationships, out these 3 events in age order. **Formation of calcite vein** **Faulting** **Deposition of limestone**	First: deposition of limestone Next, formation of the calcite vein Last, faulting, cross-cutting the beds and the vein.
The fault moved when it was deep below the surface. What would have been felt at the surface when the fault moved?	Earthquake.
If this is a fault plane has largely been quarried away here, where might the fault plane be seen now?	Logically, either to the left, or the right of the face. (It is in fact to the left, under the trees. **Do not** damage or uproot the plants on the bank.)
Use a compass to measure the direction in which the fault plane runs along the front of the face.	290^0 to 110^0 north (or roughly NW to SE).

Figures 7a & 7b. The Fault Plane at Knowle Quarry (south).

The plants on the bank here are rare and are protected.
Do not walk on, up root, or otherwise damage the plants at this site.

Suitable questions at this site.	Acceptable responses.
Ask the group to identify the ways in which the limestone is being attacked by weathering?	**Biological** weathering due to the effects of plant and tree growth. **Physical** weathering due to frost action. **Chemical** weathering by the effect of acidic rain.
What evidence can be seen for physical weathering of this face?	There is a small scree at the foot, but it is grown over so it is not currently active.
What force brought the solid lumps of rock onto the scree?	Gravity
What happens to the soluble products of chemical weathering? (e.g. breakdown products such as hydrogen carbonate and calcium ions).	They will be removed in solution by groundwater
Assuming these ions are not precipitated, where will they end up?	Springs will feed them into river flow and then to the sea.
Water will evaporate from the sea, but what will happen to the dissolved salts in the seawater?	Eventually precipitated directly when evaporation is strong and circulation is weak, or used by animals to make shells.
When the animal dies what happens to the shell?	Accumulates in the sediment, and may form part of a shelly limestone in the future.
If these new limestones become buried how will they become exposed to weathering at the surface to start a new rock cycle?	Uplift by Plate Tectonic forces
Point out to the group that **The Principle of Uniformitarianism** suggests this same re-cycling happened to the calcite which now forms these limestone rocks. Ask how long is this last rock cycle, approximately? [Emphasise the constant re-cycling of crustal material through geological time, via the rock cycle and that the evidence for several cycles are missing here because of erosion]	At least 420 million years between chemical weathering of the ancient rock to form these limestones and the weathering today.

Site 5: Knowle Quarry Lime Kilns

☛ Continue along the path in a northerly direction until the refurbished bank of Knowle Quarry Lime Kilns appears on your right. View the circular holes in the tops, for loading the kilns and then go on past the end of the bank of kilns and follow the path round to the right until you arrive at the front of the kiln bank. (See **Figures 2 & 9**).

These kilns have recently been refurbished by the National Trust, but date from the early twentieth century. Kilns have operated in this area for more than 500 years, but the last one was fired in the mid 1960s.

Figure 9. Site 5: Knowle Quarry Lime Kilns.

Suitable questions at this site.	Acceptable responses.
What elements make up the mineral calcite (calcium carbonate)?	**Ca, C** and **O**.
What are the most common elements in the Earth's crust?	**Si, O, Al** (Earth has a "glass" lithosphere - with some 40% "impurities").
Why doesn't the composition of these limestone rocks reflect the composition of the crust?	Sedimentary processes can produce beds showing chemical separations. First by way of sorting by density and size. Hence sandstones are high in **Si** and **O,** whilst clays and shales are high in **Si, Al** and **O.** Second by chemical (or organic) precipitation from seawater occurs, then elements in solution (e.g. **Ca, Na**, etc) can become concentrated in the rocks as limestones or evaporites. Third, anaerobic decay of organic matter can produce concentrations of (hydro) carbon, or coal and oil.
Ask the group "What was this construction in front of them was used for?	It was a lime kiln built and used from about 1920 (i.e. almost 100 years old).
Limestone, **$CaCO_3$,** was burned (with coal, or, originally, charcoal) at temperatures around 900^{0}C. What, chemically, would you expect to happen to the limestone?	**CO_2** would be driven off leaving Calcium Oxide, (**CaO**) or "quicklime". [Some may remain in the bottom of the kilns. DO NOT TOUCH IT.]
How was the limestone moved out of the area, and the coal for the kilns moved into the area from Coalbrookdale? [**Prompt**: Ask about the railway in Much Wenlock]	By the railway line completed from Buildwas as far as Much Wenlock by 1862 and extended to Presthope soon after. [It ran along just the other side of the B4371].
Inspect the stone work in the front of the kiln. Can you see any evidence of weathering?	Chemical weathering of the mortar between the stones. Growth of ivy on the left, promoting biological weathering.
Why were the arches to the kilns built from red brick?	They are stronger and regular in shape than the limestone, able to hold the weight above them.

Figure 10. Approach to Site 6: Jack Mytton Pathway.

☛ Return round the northern end of the lime kilns and then follow the path uphill to the Jack Mytton pathway along the crest of Wenlock Edge (See **Figure 2**).

Take the Jack Mytton Way north-eastwards along the western edge of Lea Quarry for about 200 metres towards the top of the rise. **Site 6** is along the left hand side of the pathway.

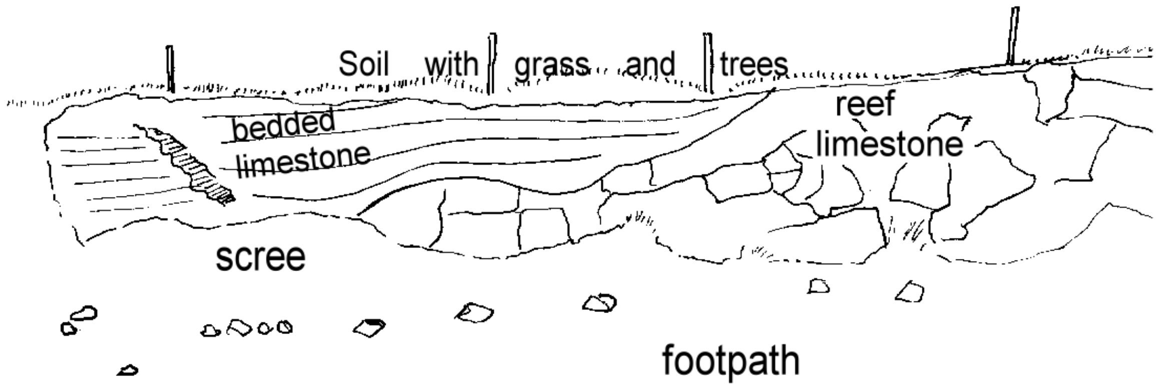

Figure 11. Sketch of Site 6.

Site 6. The Jack Mytton Pathway.

☛ It is permissible to collect specimens from this site, however, restrictions should be placed on the amount removed. The rule is "**as many pieces as can be carried in one hand**".
NOTE: Collecting should be allowed after the completion of the exercises, with an emphasis on understanding the pieces as evidence of earth science events and that they should not be removed from their context in ignorance.

Suitable questions at this site.	**Acceptable responses.**
Remind the group of the face at Knowle Quarry and ask them what features of similarity they can see here?	Thinly layered beds, more massive and jointed grey rocks.
What name is given to the grey un-bedded rocks?	They are reefs (and the group should have noticed there are a great many in the area at this time, reflecting a healthy tropical shallow shelf sea ecology 420 million years ago.
Group leaders may want to use **worksheet 7** compare the beds here with those seen at The Ercall.	The Ercall beds indicate an eroded land area being buried by very shallow-sea sands and shales. At Wenlock these beds indicate a (slightly deeper) shallow shelf sea with healthy reef formations.
These beds on J.M. Way are uphill from Knowle Quarry. Are they likely to be older or younger?	Younger, because they lie above the other beds.
Ask the group to inspect the layered face more closely and see if they can identify two rock types. There is no need to climb on the face.	The thin limestone beds are much more obvious than the thinner clay beds (that weather to produce the brown "soil" on the face.)
Ask the group to look closely at the grey jointed rock. What can they see?	Fine grained grey calcite (effervesces with dilute HCl.) with some fossils (and calcite veins).
What weathering products from this face can be seen?	Lumps of the yellowy limestone and loose brown clay.
Ask the group to see if the beds are horizontal or dipping?	They appear horizontal in the face, but in fact are dipping about 10^0 to the SE. i.e. towards the quarry.
Ask the group what would happen to rainwater falling on the top of Wenlock Edge as it drained away underground.	It would percolate through the jointed limestone and along the bedding planes to wards the quarry.
What force would be acting on the water during its trip?	Gravity.
The quarry manager has placed a large amount of waste rock against the steep wall of the quarry below the footpath. Can you suggest why?	The mass of limestone might slip along the (wet) bedding planes under gravity when the rock holding it back was removed from the quarry below. The mass of (waste) rock placed against the quarry wall is to hold back the now-unsupported rock above.

☛ Bring the group's attention to the quarry to the east, but remain on the footpath side of the boundary fence.

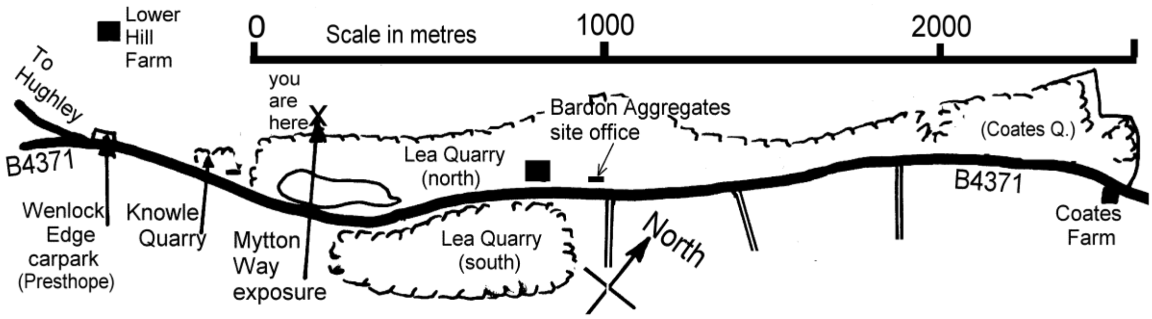

Figure 12. Sketch map of Lea Quarry (north).

Suitable questions at this site.	Acceptable responses.
Ask the group for their impressions of the quarry site.	It is an amazing sight and will elicit a range of responses. Listen to them all.
Ask why the quarry has been dug.	Its for limestone – a lot of limestone!.
Using the map on **worksheet 9** estimate the length and width of the quarry between Coates Farm and Knowle woodland to the SE	2500 metres long About 200 metres wide (Use rounded numbers)
Estimate the volume of rock removed from this one site. The Specific Gravity of Calcite is 2.71 (which could be rounded to 2.5 for a low estimate).	2,500,000 cubic metres. est. Sp Gr 2.71 x 2,500,000 = 6775000 tonnes est. 2.5 x 2500000 = 6250000 tonnes est.
What would the lime have been used for? [Reference here is made to the bulk uses of limestone. In fact it is used in a vast number of products from toothpaste to a dietary additive in bread.]	Traditionally lime was used to **lime wash buildings** and in **mortar**. Calcium oxide mixed with water was used as an alkaline **field dressing** to improve fertility where the soil was acidic, or had been leached by acid rain. It was also used as a **flux in iron making** (in Coalbrookdale) to form a slag with impurities in the ore, and it was used as a **building stone** in Much Wenlock, In the 20th century it was used as a **road ballast** on the M54 slip roads (it was not strong enough for the main roadway) and **Cement** was made from Wenlock Limestone from 1890 to the 1930s. Since 1980 slabs, pipes and artificial stone has been made from cement and limestone dust. Slaked lime (quicklime plus water) is also used to **counteract acidity in lakes** caused by acid rain.
Why might the quarrying have stopped? [Lea Quarry (south), the last active site in the area, was “mothballed” in July 2007]	There is a lot of limestone in reserve here. The main reason is reduction in demand: e.g. closure of iron works, little road building since the M54. (and a building recession looming in 2008!)
How was the limestone moved from the quarry during the twentieth century?	By road in large lorries
What difficulties might this have caused? (Dust is less of an issue as the quarry facilities allow for lorries to be hosed down before leaving the site.)	Increase in traffic on small country roads and in towns and villages.
Ask the group to weigh up the advantages and disadvantages of having a limestone quarry on Wenlock Edge.	Jobs and a vast range of products. Noise and landscape impact.
Talk through the possible solutions, or ways of offsetting the disadvantages.	e.g. Screening the quarry with trees and slopes; hosing down lorries before they leave
Point out to the group that the reason we have limestone quarries is that we need the limestone for a wide variety of products (e.g. roads, houses etc). Ask the group how they think their lives would be affected if there was no limestone quarrying?	You may need to prompt: no cement, no mortar, no building stone, no aggregate = no roads, villages towns or cities as we know them.

☛ **Worksheet 10** may be used here to summarise the geological series of events for this site, or may be used as a homework exercise.

☛ Extensions can be made to this ESO-S visit to the National Trust at Cardingmill Valley and to the Lea Quarry, run by Bardon Aggregates, **provided the arrangements are made well in advance.**
Contact details are:

The **National Trust** website: **http://www.cardingmillvalley.co.uk**
Bardon Aggregate: Telephone: 01743 709287.
Email: Quarry Manager: mark.ford@aggregate.com
Aggregate Industries Geologist: thomas.clifford@aggregate.com

☛ Return southwards along the path to the end of Lea Quarry, and then continue straight on, along the crest of Wenlock Edge until you return to Presthope car park. (See **Figure 2**).

Take care as there are several flights of wooden steps along the route, which can become slippery.