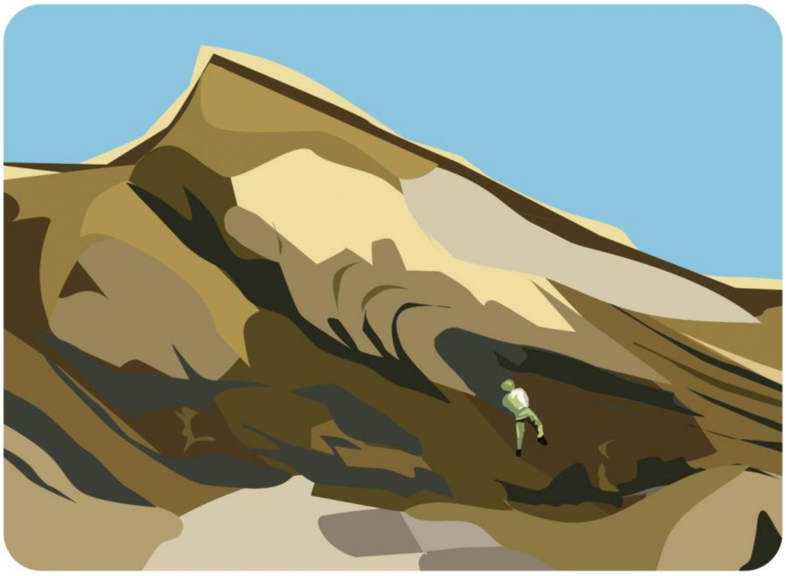
Teaching the Dynamic Earth

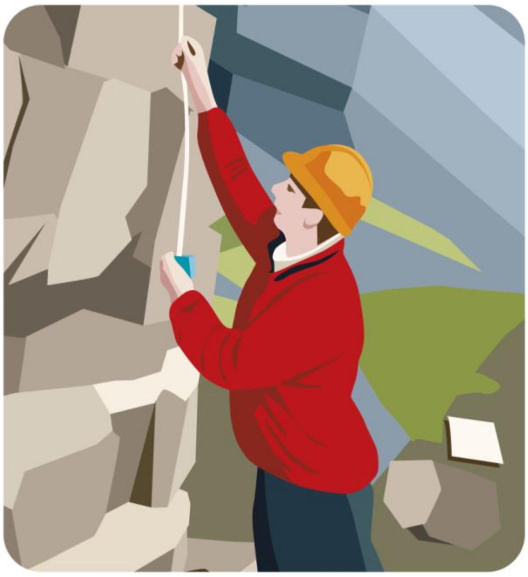
Any quarry guide: good questions to ask and answers at a quarry, cliff or rock face

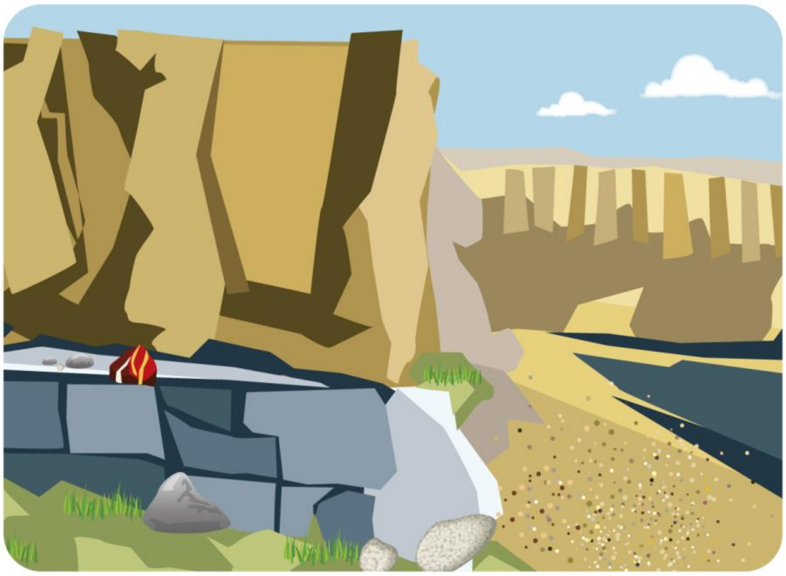
Earth science out of doors

ESEU KS3 science/geography workshop material

Earth science for KS3







EARTH SCIENCE EDUCATION UNIT

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ESEU Secondary Workshops
Earth science for KS3 science/geography

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Any quarry guide:
good questions to ask and answer at a quarry, cliff or rock face

Teacher Pack.
This Pack provides the background to the organisation of a group visit to an old quarry, natural rock exposure or cliff section. It includes possible answers to each of the questions raised. Use the accompanying Pupil Pack to select which question sheets apply to your own situation.

Contents

Topics which are *not* covered by video filming in our case-study quarry are shown in *italics.*

Summary

You want to take your students on a field visit to a local rock exposure, but are not sure what to do with them when you get there. This is a guide to the sorts of scientific questions you might ask to encourage them to investigate the rocks. Some will be appropriate for your site, some won't. Some require students to touch and examine a rock face closely; others can be answered from a safer distance.

Earth Science Education Unit workshops

These workshops have been devised for teachers and trainee teachers. They are intended to provide participants with a range of activities that can be used in the classroom, whilst helping them to develop the skills for using the activities in an engaging and motivating way that will enthuse and educate their pupils, whilst developing their critical thinking skills. The workshops should also develop the background Earth science knowledge and understanding of the teachers involved.

The workshop format may be transposed directly into a classroom, but often this is not appropriate. Similarly, individual activities, and the worksheets on which these are based, may be transferable directly into a classroom situation, but will often require modification for the classes and situations in which they are used, during which suitable risk assessments are undertaken.

Workshop Outcomes

The workshop and its activities provide the following outcomes:

- use of outdoor opportunities identified for enhancing the teaching of Earth science at KS3;
- approach Earth science more effectively through a 'How science works' context.

Curriculum references

England	Scotland	Wales	Northern Ireland
Science: Lower KS2 **Years 3 and 4** **Working scientifically** • asking relevant questions and using different types of scientific enquiries to answer them • setting up simple practical enquiries • making systematic and careful observations • using results to draw simple conclusions, • using straightforward scientific evidence to answer questions or to support their findings **Year 3** **Rocks** • compare and group together different kinds of rocks on the basis of their appearance and simple physical properties Linked with work in geography, pupils should explore different kinds of rocks, including those in the local environment Pupils might work scientifically by: observing rocks, including those used in buildings and gravestones, and exploring how and why they might have changed over time; using a hand lens or microscope to help them to identify and classify rocks according to whether they have grains or crystals, and whether they have fossils in them. **Science: Upper KS2** **Working scientifically** • recording data and results of increasing complexity using scientific diagrams and labels, classification keys, tables, scatter graphs, bar and line graph **KS3** **Working scientifically**: • ask questions and develop a line of enquiry based on observations of the real world, alongside prior knowledge and experience. • make predictions using scientific knowledge and understanding • select, plan and carry out the most appropriate types of scientific enquiries to test predictions, including identifying independent, dependent and control variables, where appropriate. • use appropriate techniques, apparatus, and materials during fieldwork and laboratory work, paying attention to health and safety. • make and record observations and measurements using a range of methods for different investigations; and evaluate the reliability of methods and suggest possible improvements. • apply sampling techniques. **KS3 Chemistry**: • the rock cycle and the formation of igneous, sedimentary and metamorphic rocks. **Geography:** **Geographical skills and fieldwork** **KS1** • use simple fieldwork and observational skills to study the geography of their school and its grounds and the key human and physical features of its surrounding environment. **KS2** • use fieldwork to observe, measure, record and present the human and physical features in the local area using a range of methods, including sketch maps, plans and graphs, and digital technologies. **KS3** • use fieldwork in contrasting locations to collect, analyse and draw conclusions from geographical data, using multiple sources of increasingly complex information. **Human and physical geography** **KS3** understand, through the use of detailed place-based exemplars at a variety of scales, the key processes in: • physical geography relating to: … rocks, weathering and soils	**Sciences** **Second** **Earth's materials** Having explored the substances that make up Earth's surface, I can compare some of their characteristics and uses. SCN 2-17a **Third** Through evaluation of a range of data, I can describe the formation, characteristics and uses of soils, minerals and basic types of rocks. SCN 3-17a **Social studies** **People, place and environment** **Early** I explore and discover the interesting features of my local environment to develop an awareness of the world around me. SOC 0-07a **First** I can describe and recreate the characteristics of my local environment by exploring the features of the landscape. SOC 1-07a I can consider ways of looking after my school or community and can encourage others to care for their environment. SOC 1-08a Having explored the landscape of my local area, I can describe the various ways in which land has been used. SOC 1-13a **Second** I can describe the major characteristic features of Scotland's landscape and explain how these were formed. SOC 2-07a **Third** Having investigated processes which form and shape landscapes, I can explain their impact on selected landscapes in Scotland, Europe and beyond. SOC 3-07a	**Science: KS2** **The sustainable Earth** • a comparison of the features and properties of some natural and made materials • how some materials are formed or produced **Geography: KS2** **Pupils develop their geographical skills, knowledge and understanding through learning about places, environments and issues** • fieldwork to observe and investigate real places and processes **Science** **KS3** Enquiry • Pupils should be given opportunities to carry out different types of enquiry, *e.g. pattern-seeking, exploring, classifying and identifying,* **Geography** **KS3** **Pupils should be give opportunities to:** • observe, measure, extract and record data through carrying out practical investigations and fieldwork **carry out:** • fieldwork to observe and investigate real places and processes **ask and answer the questions** • what are the features, the processes and patterns of this place/ environment and why do they occur?	**The world around us** **Foundation stage** **Strand 3: Place** **KS1** **Features of the immediate world and comparisons between places;** • about materials in the natural and built environment (G); (H); • about the properties of everyday materials and their uses (S&T); • the similarities and differences between buildings features and landscape in their locality and the wider world (G) **KS2** **Ways in which people, plants and animals depend on the features and materials in places and how they adapt to their environment;** • about the origins of materials (S&T) **Science** **KS3** • develop skills in scientific methods of enquiry to further scientific knowledge and understanding: planning for investigations, obtaining evidence, presenting and interpreting results **Geography** **KS3** • develop enquiry and fieldwork skills: questioning, planning, collecting, recording, presenting, analysing, interpreting information and drawing conclusions relating to a range of primary and secondary sources

Any quarry guide

Activity in brief:
You want to take your students on a field visit to a local rock exposure, but are not sure what to do with them when you get there. This is a guide to the sorts of scientific questions you might ask to encourage them to investigate the rocks. Some will be appropriate for your site, some won't. Some require students to touch and examine a rock face closely; others can be answered from a safer distance.

- These questions could be applied to many rock faces such as found in abandoned quarries, cliffs, cuttings, etc. They are usually not appropriate for working quarries, which provide a different sort of experience.
- Consult a fieldwork safety guide before you go – and follow the recommendations
- Follow the school/college/LEA guidelines on fieldwork
- Visit the site beforehand to check out the possibilities/dangers
- Ask permissions
- Prepare the students before you go
- Ensure the students have proper clothing and footwear, including safety helmets if necessary
- Follow up the fieldwork when you get back to base
- The students are your sole responsibility, take every care for their safety and education
- Running safe and educational fieldwork involves much more than just the key points above – consult widely to achieve best practice

During a field visit, you will probably want to get the most out of a rock exposure to teach or reinforce elements of the National Curriculum or to broaden the thinking of the pupils/students to consider how the Earth impacts on their lives. Each suggested series of questions focuses on one element of possible investigation, with the objectives and a suitable site suggested and final questions inviting a summary of the findings or further reflection.

Questions to Promote Investigation

Focus 1	**Weathering**
Objective(s)	• To introduce physical, chemical and biological aspects of weathering and their manifestations in the field • To provide opportunities to emphasise that weathering occurs *in situ* (in place) and movement of solid material away is not involved (although liquids can be/are removed)
Suitable site in the quarry	A place where there are clean or recently broken rock surfaces that can be compared with more weathered surfaces

Possible questions	**Possible answers**
• Are some rock surfaces more crumbly than others of a similar type?	• More exposed surfaces may have looser grains than protected ones
• What might have caused the rock surface to crumble?	• In permeable rocks, freeze-thaw (physical) and chemical effects are most likely to loosen grains
• Are some rock surfaces discoloured when compared with others?	• Natural discolouration is due to chemical attack
• Are plants/lichens found on some surfaces?	• These are causing biological weathering with biochemical attack on the rocks and roots prising apart grains and cracks
• What is the name of the processes that loosens and discolours rock faces without removing grains?	• Weathering
• Are the rocks lightly, moderately or heavily weathered?	• Asks pupils to give a feel for the scale of the weathering

Focus 2	**Erosion**
Objective(s)	• To highlight erosion by gravity and/or water • To provide opportunities to emphasise that erosion involves the removal of solid material
Suitable site in the quarry	An area of loose rock beneath a rock face, preferably with water-formed gullies leading away

Possible questions	**Possible answers**
• How did the pile of rock fragments build up at the bottom of the rock face?	• Broke off and fell – caused by gravity (or gravitational pull on the mass of the loosened rock fragment)
• How else are fragments being carried away from the rock face? • How can you tell?	• Water carries fragments down gullies. You may see water-worn gullies and small fans of sandy/muddy sediment ('Pupil power' may be causing erosion too)
• What is the name of the process that removes fragments from rock faces?	• Erosion
• Are the erosive processes here acting slowly, at moderate rates or quickly?	• Encourages pupils to think about rates and timescales

Focus 3	**Soil**
Objective(s)	• To consider how soil develops from the parent rock
Suitable site in the quarry	A place where a clear soil profile has developed at the top of a rock face, and can be seen in cross section
Possible questions	**Possible answers**
• How many different soil layers can you see?	• Often three, an organic (dark) upper layer, a mixed middle layer and a rocky lower layer
• How does rock become changed into topsoil?	• The rock becomes broken up into fragments, more and more organic activity takes place until topsoil forms
• Is this a rich or poor soil? (Generally, the greater the number of species, the richer the soil)	• Soils on top of rock faces are generally thin and poor

Focus 4	**Rock group**
Objective(s)	• To distinguish between sedimentary and igneous rocks (for simplicity, metamorphic rocks are ignored in this exercise) • To consider the main lines of evidence that can be used to tell the difference
Suitable site in the quarry	A place where the rock characteristics, either in the rock face itself or in debris at the foot of the face, are clear and obvious
Possible questions	**Possible answers**
• Can layers be clearly seen in these rocks? (Most sedimentary rocks are clearly layered; most igneous rocks are not)	• Layering is clear (= sedimentary bedding) or no layering can be seen (= igneous). Don't confuse parallel cracking with layering (= joints) – in sedimentary bedding, beds often differ in grain size, colour, etc.
• Does a drop of water sink in or run off the surface? (Most sedimentary rocks have gaps between the grains so that water sinks in. Most igneous rocks have interlocking grains making them waterproof)	• Porous = sedimentary (unless the rock is very well cemented or has undergone metamorphism). Non-porous = igneous (unless the rock is well weathered)
• Can you scrape grains off the surface? (Grains can be scraped off the surface of most sedimentary rocks, but are much harder to remove from most igneous rocks)	• The interlocking nature of igneous crystals make them much harder to remove
• Does one drop of dilute acid react with the rock? (Some sedimentary rocks react with acid, but igneous rocks don't)	• Limestones react with acid; some sandstones have lime cement that reacts. Metamorphosed limestones (= marble) also react with acid. No igneous rocks in the UK react with acid
• Can you spot any fossils? (Sedimentary rocks can contain fossils, igneous rocks never do)	• Fossils can be found in some sedimentary rocks as well as in some low-grade metamorphic rocks
• Is this rock an igneous or sedimentary rock? How do you know?	• Encourages pupils to assemble all the evidence to answer

Focus 5	**Grains**
Objective(s)	• To consider how grain size evidence in sedimentary rocks can be used to indicate the energy level of the environment during deposition • Using evidence from grain shape and sorting to give clues to the ancient transportation regime
Suitable site in the quarry	A place where grains can clearly be seen and preferably where there is some variety of grain size/shape. A hand lens may be helpful for finer-grained rocks

Possible questions	**Possible answers**
• How big is the largest grain you can see? • (Estimate the length in mm or cm)	• Boulder, pebble, sand or mud-size
• When the sedimentary grains were being laid down, how might they have been moved here – by wind, water, ice or gravity?	• Most sediments are water-lain and can contain grains up to pebble size (cm across). Wind-lain deposits contain mainly sand-grade sediment. Gravitational fall deposits (e.g. screes) or ice deposits can contain large boulders
• Was this deposit laid down in low, medium or high energy conditions? (Large grains take more energy to move and deposit them than smaller grains)	• In water-lain deposits, large particles are laid down by high energy flash floods or storms at sea; sands and muds are lower energy deposits
• Does the rock have several sizes of grains or just one size? (The further grains are carried, the more they tend to be sorted out into coarse, medium and fine sizes)	• Mixed sediment (pebbles, sand and mud together) is probably near-source and was dumped in a storm. Separated sediment (pebbles, sand or mud) has been sorted out during longer transportation (long river transport or much movement in the sea)
• Have these grains travelled far? (Grains with sharp corners have not moved far but rounded pebbles will have travelled a long way; also, the further they have travelled, the more different sorts there are likely to be)	• As grains are transported they abrade one another (attrition) becoming rounded as corners are removed • The greater the transportation distance (or movement in the sea) the more different rock types are likely to be incorporated
• What does the grain evidence tell you about this sedimentary deposit?	• Invites a summary of the evidence

Focus 6	**Sedimentary structures**
Objective(s)	• To use sedimentary structures to bring an ancient environment 'to life'
Suitable site in the quarry	A place where sedimentary structures likely to be familiar to pupils/students are clearly visible, examples might include bedding (sedimentary layering), cross bedding (sloping beds in an otherwise flat-lying deposit), asymmetrical (current) ripples or symmetrical (wave) ripple marks, mud cracks, footprints, large-scale dune cross bedding

Possible questions	**Possible answers**
• If you were standing here when this sediment was being deposited, what would it have been like?	• The structures listed above form on land (dune cross bedding), in drying water deposits (mud cracks, footprints), in wave-dominated areas (wave ripples) or where there were water currents – usually shallow water (current ripples). Bedding forms in water-lain deposits at most depths, from lakes to deep seas
• Would you have been on land or in water? • If in water, how deep? Would you have needed a snorkel, scuba gear or a submarine?	
• Could you have stood up? Would the current have been too strong or the sediment too sloppy?	
• What would you have been able to see, hear, taste, smell?	• Stretches the imagination – helps to visualise what it actually might have been like at the time. Invites comparison with modern environments
• What is the altitude here (e.g. from a map)? • How has the altitude changed since the sediment was deposited?	• It may have changed by metres, hundreds of metres, or kilometres

Focus 7	**Fossils**

Objective(s)	• Fossil preservation depends on:
	  ◦ the characteristics of the organism
	  ◦ what happened straight after death
	  ◦ what happened after burial
	• Fossils can provide useful evidence of several different sorts

Suitable site in the quarry	A place where fossils are clearly visible, the more variety, the better

Possible questions	**Possible answers**
• What happened to these animals/plants just after they died? • Were they buried where they were or moved around, sorted out and broken up?	• Organisms can be buried just where they lived (a 'life assemblage') but are more likely to have been swept away to form a 'death assemblage'. They could be deposited in a quiet area where they are likely to be well preserved, they could accumulate in a bank of broken material, or they could be something in between
• As they were being buried, what might they have looked like, smelled like?	• Focuses on the fact that these were living things that were preserved
• After they were buried, how did they change?	• In nearly all fossils, the soft organic parts have decayed leaving only the hard parts behind. These are preserved either as they were (with little chemical change) or chemically altered. Sometimes percolating fluids dissolve the organism leaving a mould and may later fill it with minerals, forming a cast • The pressures of low-grade metamorphism can deform fossils without destroying them
• Why are some types of organism much more commonly fossilised than others?	• It depends on the organism (size, numbers, presence of hard parts, etc.) • … and the environment in which it lived/died (mud-burrowers are more likely to be preserved than mountain goats)
• What can fossils tell us about a deposit?	• That there was life around at the time • The type of life and type of environment (wet/dry; hot/cool; shallow/deep; salt/fresh, etc.) • The relative age of the deposit • How evolution was progressing at the time

Focus 8	**Crystals**
Objective(s)	• To use crystal size to distinguish between intrusive and extrusive igneous rocks
Suitable site in the quarry	A place where the crystals in an igneous rock can be seen clearly (using a hand lens)

Possible questions	**Possible answers**
• How big is the largest crystal you can see? (Estimate the length in mm or cm)	• Coarse (cm size), medium (mm size) or fine (crystals difficult or impossible to see)
• Did the melt (magma) that formed this rock cool quickly or slowly? (Slow cooling = large crystals, faster cooling = smaller crystals)	• Coarse = slow cooling, e.g. over hundreds of thousands or millions of years; fine = fast cooling in lavas over days or weeks
• Did the melt (magma) become solid at the surface (fine-grained) or beneath the surface (coarser)?	• Coarse-grained (intrusive) rocks formed well beneath the surface (e.g. at km depth) when the insulating rocks above resulted in slow cooling. Fine-grained (extrusive) rocks were usually lavas, chilled at the surface
• Does the rock have crystals of different sizes? • How might this have happened?	• Some magmas have two stage cooling. After starting to crystallise at depth producing larger crystals, they rise and cool more quickly forming a fine crystal groundmass • Other intrusions have large crystals at the centre, but 'chilled margins' of finer crystals against the cooler surrounding rock

Focus 9	**Tilted rocks**
Objective(s)	• To use evidence of local deformation to appreciate wider scale tectonic events
Suitable site in the quarry	A place where once horizontal (usually sedimentary) rocks are now tilted (dipping)

Possible questions	**Possible answers**
• Were these sediments laid down flat?	• Yes – the majority of sediments were. Exceptions include cross bedding and bedded scree deposits
• What is their angle now?	• Estimate the dip – the angle of slope measured from the horizontal
• What might have caused a change in angle on this scale?	• Dipping rocks are evidence of regional deformation – which can normally only be caused by the collision of tectonic plates. This produced fold mountains in central areas and broad folds with tilted rocks on the margins
• Which came first, the deposition of the sediments or the tilting?	• Sediments must have been deposited before tilting. Encourages pupils to begin sequencing events

Focus 10	**Folds**
Objective(s)	• To show that folds are the result of compression by large scale equal and opposite forces • To indicate the scale of forces necessary to fold rocks – that can only be related to plate movement
Suitable site in the quarry	A site where sedimentary rocks are folded into simple folds, preferably several of them

Possible questions	**Possible answers**
• Were these sediments laid down flat?	• Yes – the majority of sediments were
• Why are they no longer flat?	• They were squashed/compressed
• From which directions did the forces come that caused the rocks to crumple like this?	• Equal and opposite forces are likely to have acted horizontally at right angles to the axis of the fold
• What might have caused this scale of crumpling?	• Folded rocks are evidence of regional deformation – which can only be caused by the collision of tectonic plates. Folds are produced on a range of scales, from fold mountains to cliff faces and smaller
• How could hard rocks have been bent and folded in this way?	• The rocks may have been more plastic (less brittle) at the time, and would certainly have been more deeply buried and so warmer - but this is evidence of the enormous pressures and high temperatures involved in plate collisions

Focus 11	**Faults**
Objective(s)	• To highlight the differences between faults and other types of fractures • To link faulting to regional stress patterns
Suitable site in the quarry	A site where rocks are clearly faulted, preferably where beds can be matched up on either side of the fault

Possible questions	**Possible answers**
• How can you tell that this fracture is a fault? (Faults are fractures where the rocks on either side have moved)	• Layers or rocks do not match up across the fault
• What types of forces might have caused this fault, squeezing, pull-apart or sliding forces? (Faults can be caused when rocks are squeezed, or pulled apart or rocks slide past one another. Faults caused by squeezing usually slope downwards at less than 60^{o}, steeper faults are usually caused by pull-apart forces. Sliding faults are usually vertical)	• Compressional forces (squeezing) cause reverse faults where one slice of rocks has been thrust over another • Tensional (pull apart) forces cause steep faults (called normal faults) where one block slides down, adjacent to the other • Shear (sliding past) forces usually produce vertical tear faults • If a rock sequence can be matched up across a fault, the type of fault is confirmed
• How can some rocks be both faulted and folded?	• At relatively high temperatures and pressures, rocks tend to behave plastically and bend, whilst at lower temperatures they have brittle behaviour and fracture
• What might have caused the squeezing, pull apart or sliding forces that fault rocks?	• Most faulting is related to the movement of tectonic plates, although there may be local causes as well • Plate collision causes reverse faults (and often folding too) • Plate divergence produces normal faults as blocks fracture and slide up or down relative to one another • Plate sliding at conservative margins (like the San Andreas fault) causes tear faulting

<table>
<tr><td>Focus 12</td><td colspan="2">Metamorphism</td></tr>
<tr><td>Objective(s)</td><td colspan="2">To illustrate how metamorphic rocks formed from pre-existing rocks
To show what differences the metamorphism causes</td></tr>
<tr><td>Suitable site in the quarry</td><td colspan="2">An exposure of metamorphic rocks, preferably containing evidence of their former origin</td></tr>
<tr><td colspan="2">Possible questions</td><td>Possible answers</td></tr>
<tr><td colspan="2">How can you tell that this is a metamorphic rock?</td><td>Having recrystallised under great heat and/or pressure, metamorphic rocks are usually hard and non-porous.
Pressure-formed metamorphic rocks that were formed on a regional scale have crystal alignments that cause the cleavage in slates, the layering effects in schists and the banding in gneisses</td></tr>
<tr><td colspan="2">What clues show what sort of rock this was before metamorphism?</td><td>Sedimentary rocks may retain original bedding or cross bedding traces
Marble reacts with dilute acid, like the limestone it formed from
Low-grade metamorphic rocks (slates and some marbles) may retain fossils which may have been distorted (squashed)</td></tr>
<tr><td colspan="2">What are the differences between this metamorphic rock and the rock it probably formed from?</td><td>Harder and less permeable
Original traces may be distorted/destroyed</td></tr>
<tr><td colspan="2">How might these differences have been caused?</td><td>In the roots of mountains during plate collision and fold mountain formation (forming pressure-formed metamorphic rocks on a regional scale)
Baking adjacent to a hot igneous intrusion</td></tr>
</table>

Focus 13	Sequencing
Objective(s)	• To use geological 'relative dating' methods to work out the sequence of geological events at a site
Suitable site in the quarry	A site where several geological events have left clear signs

Possible questions	**Possible answers**
• In a layered sequence, which of the layers was formed first? Which last?	• The last (youngest layers) are on top (unless major geological upheavals have overturned the whole sequence – very unusual). This is the 'Principle of Superposition of Strata'
• Where a feature cuts across another feature, which came first, the feature that cuts through or the feature that is cut?	• The feature that is cut is always older than the feature (such as a fracture, fault, dyke or erosion surface) that cuts across it. This is the 'Law of Cross-Cutting Relationships'
• If a rock A contains pebbles of another rock B, which came first, rock A or rock B?	• The pebbles of B must be older than rock A that contains them. This is the 'Law of Included Fragments'
• If a rock is tilted, folded or metamorphosed, which came first, the rock or the tilting/folding/metamorphism?	• The rock must have been formed before the tilting, folding or metamorphism happened
• What is the sequence of geological events at this site using these methods?	• Most geological histories begin with the deposition of the oldest rock and end with the erosion that exposed the rock you can see today

Focus 14	**Tectonic plates**
Objective(s)	• To consider the geological evidence from the quarry in a plate tectonic context
Suitable site in the quarry	Any site with reasonable exposures

Possible questions	**Possible answers**
• Are there clues that suggest that this place had a very different climate in the past?	• Coral fossils – colonial corals are only found today in tropical and sub tropical seas • Limestone – thick limestone deposits only form today in tropical and sub tropical seas • Coal – thick organic deposits that form coal accumulate today in equatorial conditions • Red sediments – these form today in tropical and subtropical conditions
• What might have caused the change in climate between then and now?	• This place is on a moving plate that was much further south in the past
• Are there clues showing that this place was near a plate margin in the past?	• Evidence of a compressional plate margin, with fold mountains and metamorphism and the plate being carried down into the mantle (subducted) producing intrusive and extrusive rocks includes: folding, tilting, reverse faulting, regional metamorphic rocks, intrusive and extrusive igneous rocks • Any normal and tear faulting is difficult to tie in to a plate margin model in the UK – they are likely to be due to more local effects
• Are there clues that show whether or not this area is near a plate margin now?	• Absence of clues is evidence. There are no earthquakes, volcanoes, or new mountain chains characteristic of a plate margin in the UK – because the nearest compressional (convergent) margin is around 1500 km away in the Mediterranean and the nearest tensional (divergent) margin is around 1500 km away in the mid-Atlantic • Although minor but usually non-damaging earthquakes do occur in the UK, they also occur within all plates as they adjust to the forces at the plate margins

Focus 15	**Landscape**
Objective(s)	• To provide a feel for how rock resistance, structure and use affect landscape
Suitable site	A viewpoint from where higher and lower land, hills and valleys or headlands and bays can be seen

Possible questions	**Possible answers**
• Which landform is formed of the most resistant (hardest) rocks? • Which is made of the least resistant (softest) rocks?	• In general, high land, hills and headlands are made of resistant rocks, whilst lower land, valleys and bays have been eroded in less resistant rocks
• How might ridges form?	• Tilted rocks of alternating resistant and less-resistant sequences often produce ridges
• How might flat-topped plateaus form?	• Most plateaus are caused by flat-lying resistant rocks
• When you walk downhill are you normally walking from softer towards harder rocks or visa versa?	• The latter
• How can the human use of rocks affect landscape?	• Quarries, walls, buildings, dams/reservoirs, bridges and cuttings, graveyards, monuments and statues

Focus 16	**Quarry economics**
Objective(s)	• To give a feel for the commercial value of materials from the Earth – and their importance to us • To develop arithmetical and estimation skills
Suitable site	A quarry!

Possible questions	**Possible answers**
• What are the dimensions of this quarry (length, breadth and height)	• Estimate length and breadth by pacing • Estimate height on the basis that an average teacher (if there is such a thing!) is around 1 $^2/_3$ metres high
• What is the volume of the quarry • (Volume (m^3) = length (m) x width (m) x height (m))	• Calculators may be useful, if the students can cope with the numbers of noughts
• What is the economic value of the rocks in this quarry at today's prices? • (Value (£) = volume (m^3) x price (£m^{-3}))	As guides: • Normal building stone (e.g. sandstone or limestone) £40 m^{-3} • High quality crushed rock aggregate for road surfaces, railway ballast – (e.g. basalt, metaquartzite) = £2 m^{-3} • Lower quality crushed rock aggregate for adding to cement to make concrete – (e.g. limestone, Triassic sand) = £1 m^{-3} **Note:** • High quality stone blocks for building/repairing imposing buildings - cut to size (e.g. high quality sandstone or limestone) = £2,000 m^{-3} • Thin slabs of high quality stone for kitchen worktops – cut and finished (e.g. granite) = £8,000 m^{-3}] • Pupils/students will need help with the numbers of noughts, and the enormous value of the quarry products in bulk
• Which nearby cities/towns would be most likely to want to buy these quarry products?	• Transport costs for bulk materials like quarry products are huge – which is why they are mainly available only to local markets unless they are of high value
• What might they be used to build in the nearby city/town?	• There may be local initiatives requiring bulk materials, such a restructuring a town centre or building a runway
• Do you think the quarry might re-open?	• In 99% of cases – no. Existing quarries tend to continue and gaining planning permission for new quarries is a very difficult process – especially near urban areas

Focus 17	Quarry potential
Objective(s)	• To show that abandoned quarries can have a range of different uses, some more appropriate than others • To develop decision-making skills
Suitable site	An abandoned quarry

Possible questions	Possible answers
• Could this quarry be used to dispose of high level nuclear waste material? If so, why? If not, why not?	• Quarries would not be used to dispose of high level nuclear waste. They are too shallow and most are too near urban centres
• Could this quarry be used to dispose of household waste material? If so, why? If not, why not?	• If the rock is permeable or cracked, waste fluids or gases could escape and damage water supplies or buildings. It could be lined, but this is very expensive. There may be problems with transport, blowing rubbish or scavenging birds. But places to dispose of the huge volumes of waste we produce have to be found
• Could this quarry be used to dispose of demolition rubble? If so, why? If not, why not?	• Most quarries could safely be filled with rubble and then landscaped to match the surrounding countryside. They would need monitoring to ensure that dangerous chemicals or gases did not leak
• Could this quarry be used as a water reservoir? If so, why? If not, why not?	• It is unlikely to be large enough, and permeable rocks would leak
• Could this quarry be used as a nature reserve? If so, why? If not, why not?	• Quarries can be made safe and be made to blend in with the landscape, but this can be expensive. They do contain a range of habitats for plants and animals
• Could this quarry be used as part of a golf course? If so, why? If not, why not?	• Most golfers would be unwilling to climb down into, and back out of a quarry, although it could provide a number of interesting golf course hazards
• Could this quarry be used as part of an orienteering course? If so, why? If not, why not?	• There is probably only one access point and the rock walls would be dangerous, so probably not
• Could this quarry be used as a Regionally Important Geological/geomorphological Site (RIGS) for its scientific or educational interest or its beauty. If so, why? If not, why not?	• It clearly has educational value, because we are here • It also has scientific value because … • It is beautiful/not beautiful because … • I think there are better/not better quarries elsewhere. • It would need to be made safe by …
• Could this quarry be re-opened to supply building material? If so, why? If not, why not?	• Since the quarry is now closed, there are probably cheaper or more accessible alternatives elsewhere, so re-opening is unlikely
• Which of these options would be the best one? Might different groups of people have different points of view?	• Different groups would have different opinions, but the student should be able to justify his/her own views

Focus 18	Recording	
Objective(s)	• To consider how a scientist (geologist) would go about making effective records of a site	
Suitable site	Any site with some geological variety	
Possible questions	**Possible answers**	
• If this site were to be filled in or destroyed, in what ways could the geological information be recorded for future use?	• Specimens of all the different rock types could be collected • Each of the rocks present could be described in detail • A continuous record of the layers could be made, from bottom to top • Measurements could be made of rock thicknesses, angles and directions • Drawings could be made of all the key features • Key features and areas could be photographed • Maps or aerial photographs could be made • An exact survey of the area could be carried out	
• Which of these ways would be best? Why?	• The answer will depend on the rock type, features and situation. Sedimentary sequences could be logged (a continuous record made, from the bottom to the top). For all rocks, detailed rock descriptions, measurements and drawings/ photos of key features could be made. (Since to a professional geologist, the shape of the quarry is irrelevant, he/she would focus on other features)	

Resource list

Any quarry guide	**Required by**	
Resource list:	**Teacher**	**Pupil**
Optional bottle of 0.5M HCl in acid dropper (already diluted)	✓	
Wash bottle filled with tap water	✓	
Optional compass	✓	
Optional clinometer if available	✓	
Safety equipment e.g. hard hat for all if quarry face is a hazard	✓	✓
Clipboards		✓
Appropriate question sheets from the Pupil Pack		✓
Hand lens –teacher and also pupils if possible	✓	✓

Risk assessment

Each Local Authority or school/institution will have its own rules regarding off campus visits and these should be strictly adhered to. The following notes may, however, be helpful as a general guide (but this is not a legal statement).

- Obtain permission for the visit, where necessary, and inspect the site before the class visit in order to identify any specific hazards appertaining to that site. In general, look out for unstable quarry faces, deep pools, slurry lagoons, half-hidden remains of quarry machinery etc. Decide how to minimise any risks to students, e.g. by clear instructions beforehand, in writing, reiterated once on site by pointing out areas which are out of bounds. Behaviour such as throwing stones down cliff faces or running around should not be allowed.

- Ensure an adequate staff/student ratio and ensure that hazards such as road crossings and transport en route to the site are not ignored.
- Be aware that the most common time for accidents to happen is immediately after a meal break when some students have finished eating and are "relaxing".
- If a repeat visit is made another year, a site visit should still be made shortly before taking a class there.
- Your risk assessment should be approved by Senior Management at school, and filed at the appropriate school office before departure. The teacher in charge should carry a copy on the day.

Resources:
Earthlearningidea has produced a series of activities on fieldwork, including the "Any Quarry" approach above. https://www.earthlearningidea.com/home/Teaching_strategies.html#fieldwork

Safety is developed further in: https://www.earthlearningidea.com/PDF/292_Fieldwork_safety.pdf

The UKRIGS Education Project – Earth Science on Site – has produced detailed Earth science field teaching activities for schools at former aggregates sites across England. 16 such sites have been described. Freely downloadable pdf files are available on the website: http://www.geoconservationuk.org.uk/esos/wiki2018/index.php?title=Main_Page