EDUQAS A LEVEL GEOLOGY compared with EARTH LEARNING IDEAS
– an analysis by Geopix and Earthlearningidea

In this chart, the comparison between the A Level Geology specification of Eduqas has been made from the viewpoint of Geopix – it does not represent official policy of the awarding bodies; as always, the published specification should be consulted for the full version.
Earth Learning Idea and Geopix wish to thank Eduqas for kind permission to reproduce these sections of the specification.

NB With effect from May 2020, Earthlearningidea has posted a set of teaching videos and Powerpoint presentations on the website. These have been produced to help teacher educators to continue their courses online during the Covid-19 lockdown and its aftermath, but they are also of value for teachers of A Level and GCSE Geology. Many activities are demonstrated which can enliven your own teaching, either used selectively for online lessons or face-to face classes. See: https://www.earthlearningidea.com/home/Teaching_videos_workshops.html
2021/22. For our new series on zero carbon – See Appendix

EDUQAS	Earth Learning Ideas
Topic F1: Elements, minerals and rocks	
Key Idea 1: The Earth is composed of rocks which have distinctive mineralogies and textures	***Note:*** *In view of the overlap between fieldwork and many listed topics, if fieldwork is the main emphasis of an ELI, it will be mentioned under the Fieldwork heading and not elsewhere.*
a. The Earth's elements may be classified according to the Goldschmidt system (lithophile, siderophile, chalcophile, atmophile) which aids subdivision of the Earth on the basis of geochemistry (atmosphere, hydrosphere, crust, mantle and core).	Fieldwork: Environmental evaluation Developing a strategy for evaluating the environment
b. The bulk composition of the Earth is comparable with that of undifferentiated meteorites (chondrites).	
c. The Earth's crust is composed of eight main elements. Recognition of the relative abundance of O, Si, Al, Fe, Ca, Na, K and Mg in the crust and the role of the silicates as rock-forming minerals.	What am I made of? (ELI+)
d. Silicates are the commonest rock-forming minerals and are built from silicon-oxygen tetrahedra (single, chain, sheet and framework silicates). Simple analysis of silicate mineral structures from models and diagrams.	Building silicates Simulating crystal size during the cooling of magma and during recrystallization in solid rock
e. Minerals are naturally occurring inorganic chemical compounds or elements with compositions that may be expressed as chemical formulae. Minerals have distinct chemical compositions, atomic structures and physical properties by which they may be identified.	Mineral or not? Discussion about what is a mineral and what is not
f. Rocks are composed of aggregates of minerals, pre-existing rocks or fossils. g. Igneous, sedimentary and metamorphic rocks display differences of composition and texture that reflect their mode of origin.	Teaching geology to students with visual impairment (VI) Modifying geological materials for students who cannot see A forgotten rock garden - 1 Help a geologist identify a treasured outdoor collection. A forgotten rock garden - 2 Help a geologist identify a treasured outdoor collection

SP1: Investigation of diagnostic properties of minerals: colour, crystal shape, cleavage, fracture, hardness, relative density, streak, lustre, reaction with cold dilute (0.5 mol dm^{-3}) hydrochloric acid. SP2: Measurement of the density of minerals. Recognition, using appropriate tests, of the following rock-forming minerals (as specified on the mineral data sheet available for use in the examination) from their diagnostic properties: quartz, calcite, feldspars (orthoclase, plagioclase), augite, hornblende, olivine, micas (biotite, muscovite), haematite, galena, pyrite, chalcopyrite, fluorite, barite, halite, gypsum, garnet, chiastolite/andalusite.	Eureka! - detecting ore the Archimedes way Identifying minerals - use your sense(s)! Mineral expert 1 Mineral expert 2 Mineral expert 3 (ELI+) Mineral expert 4 - Recycle your mobile phone Picturing Minerals -1 Visualise and draw minerals from a verbal description Picturing Minerals -2 Visualise and draw minerals from a verbal description

Topic F2: Surface and internal processes of the rock cycle	
Key Idea 1: The mineralogy and texture of sedimentary rocks are the result of the surface process part of the rock cycle, driven by external energy sources	Not misunderstanding the rock cycle Laying out the rock cycle The rock cycle in wax The rock cycle at your fingertips From ‘Rock detective’ to ‘Laying out the rock cycle’…
a. External energy: solar heating of the Earth's surface drives the water cycle and influences weathering and erosional processes.	Cycling water and heat in the lab - and the globe (ELI+) Mini-world water cycle ‘Tagging’ water molecules - to explore the water cycle (ELI+) Water cycle world Teacher - ‘What’s the difference between weathering and erosion?’ How can storms affect erosion rates? Predict what will happen to a landscape if it is affected by a storm
b. Physical and chemical weathering of rocks occurs at the Earth's surface and provides the raw materials for new sedimentary rocks: • physical weathering, (insolation, freeze/thaw) breaks rock down into smaller fragments • chemical weathering of silicate and carbonate rocks (hydrolysis, carbonation, solution and oxidation) produces a range of new minerals and solutions together with residual, resistant minerals • biological weathering involves physical and chemical changes.	Watery world of underground chemistry (ELI+) Cracking apart (ELI+) Ice power (ELI+) Karstic scenery - in 60 seconds Weathering limestone - with my own breath! (ELI+) Weathering - rocks breaking up and breaking down Salt of the Earth: who can make the biggest salt crystal? What colour was the world in the past? Using rock evidence and ‘the present is the key to the past’ to colour the geological world Breaking up – classroom freeze-thaw weathering Showing how freezing and thawing can break porous rocks in the classroom Speeding up nature to trap carbon dioxide The potential role of enhanced weathering and carbonation in mitigating climate change

c. Surface materials are transported by a range of erosional agents and are deposited as sediments: • erosion (abrasion, attrition) • transport (traction, saltation, suspension, solution) • deposition selectively concentrates products in particular environments – • grain size related to energy of depositional environment; dominance of quartz and muscovite in coarse fraction and clay minerals in fine fraction; flocculation; precipitation	Bucket for a pothole: visualising past Changing coastlines Dust bowl Grinding and gouging Mighty river in a small gutter Mighty river in a small gutter: Investigating small-scale sedimentary processes AND modelling mighty rivers Rock, rattle and roll Rolling, hopping, floating and invisibly moving along Earth science out-of-doors: preserving the evidence Recreating the rocks – step by step: simulating a dipping sedimentary rock sequence though a sequence of Earthlearningideas What would it feel like to wriggle your toes on an ancient bedding plane as the sediment was being deposited? Clues from the present day about the origin of sedimentary rocks How many sand grains are there in a bucket – or on a beach? Planning activities to estimate the number of sand grains in a bucket – or on a beach
d. Different sedimentary environments may be identified by diagnostic sedimentary structures, rock textures, mineralogy and fossil content. Description of sedimentary rocks in hand specimen, rock exposures and diagrams/photographs from observation of their colour, texture (use of sediment comparators to determine grain size, shape and sphericity), (coarse >2 mm, fine <1/16 mm), reaction with 0.5 mol dm^{-3} hydrochloric acid, mineralogy and other diagnostic features. Identification in hand specimen of the following sedimentary rocks from their composition, texture and other diagnostic features: sandstones (orthoquartzite, arkose, greywacke), shale/mudstone, limestones (shelly, oolitic, chalk), conglomerate, breccia.	What was it like to be there? – clues in sediment which bring an environment to life Environmental detective Building Stones 3 - Sedimentary rocks Calcium carbonate question - 'I'm pure calcium carbonate' Rock around your school Rock detective - rocky clues to the past From river sediment to stripey rocks Modelling the build up of different layers of sediment as seen in sedimentary rocks. Rock grain cut out How can you tell which grains come from which rock? Urban fieldwork – the stories from materials, colours, lines and shapes: find out the stories told by materials used in building and for decoration. Playground continents: A palaeogeography in your school yard A rock is a time capsule – a message from the past: Bringing to life the extraordinary stories of ordinary rocks
e. A study of fluvial, marine and aeolian sediments demonstrates these differences. Investigation of textures of sediments from different depositional environments. Investigation of contrasts between fluvial, marine and aeolian sediments continued below/.. f. Sedimentary rocks may result from the accumulation of organic material (limestone, coal) or by precipitation of solid material from solution (evaporites).	Salt of the Earth Does my rock hold water and will water flow through it? Modelling for rocks: what's hidden inside - and why? Space within - the porosity of rocks What was it like to be there - in the rocky world? Darwin's 'big coral atoll idea' Why is the Dead Sea dead? Beach, river, dune, mountain, plain – what layers might be preserved here? A discussion on what evidence might be preserved in rocks from different environments

g. Sedimentary rocks exhibit differences in texture which influences porosity and permeability: grain angularity, sphericity, size, sorting, which reflects: • the nature of rocks from which they were derived • conditions of climate, weathering, erosion and deposition operating during their formation continued below/.. Analysis of biogenic components in sedimentary rocks.	Which sedimentary structures can you make? Making sedimentary structures in the classroom using simple apparatus and materials Picturing puzzle structures: Visualise and draw sedimentary structures from a verbal description
(e) continued Interpretation of maps, photographs and graphic logs showing the following sedimentary features: bedding, cross-bedding, graded bedding, laminations, desiccation features, ripple marks (symmetrical and asymmetrical), sole structures (load/flame, flute cast).	Cracking the clues Sandcastles and slopes Sand ripple marks in a tank Sand ripple marks in a washbowl Sedimentary structures - cross-bedding and ancient currents Sedimentary structures - graded bedding Sedimentary structures – imbrication Sedimentary structures - load casts Sedimentary structures - sole marks From river sediment to stripey rocks - modelling the build-up of different layers of sediment as seen in sedimentary rocks How do sedimentary beds form? – and why can we see them? Demonstrating how the beds in sedimentary rocks are deposited Sedimentary structures – make your own cross-bedding: classroom activities to make and explain how cross-bedding forms Which sedimentary structures can you make? Making sedimentary structures in the classroom using simple apparatus and materials
(g) continued • post-depositional factors as sediments are formed into sedimentary rocks: diagenesis and lithification (compaction, recrystallisation, cementation, pressure solution).	Under pressure (ELI+) Make your own rock The deep rock cycle explained by plate tectonics: lithification A model showing how plate tectonics can explain sediments becoming sedimentary rocks
Investigation of the concept of ‘sediment maturity’. Immature sedimentary rocks characterised by a wide range of mineral compositions and/or lithic clasts; mature sedimentary rocks with restricted mineralogies dominated by mineral species resistant to weathering and erosional processes	A bucket for a pothole: visualising past processes by calculation

F2 Key Idea 2: The formation and alteration of igneous and metamorphic rocks result from the Earth’s internal energy	
a. Internal energy: The Earth’s internal geological processes result from the transfer of energy derived from radiogenic and primordial heat sources.	The heat is on: modelling the movement of heat from the Earth’s core outwards Melting and boiling – the influence of pressure How does a reduction in pressure lower melting and boiling points?

Heat is transferred from the mantle to the surface by conduction and convection, with temperatures of rocks remaining below melting point (except locally). Interpretation of evidence for surface heat flow and temperature variation with depth through simple analysis of the geothermal gradient (geotherm).	
b. Igneous rocks are the products of cooling of magma in bodies of various sizes and shapes and pyroclastic events.	Crystallisation in a pudding dish Volcano in the lab (ELI+) *Opengeoscience* 1: igneous intrusions and lavas
The recognition of plutons, dykes, sills, lava flows and pyroclastic deposits by interpretation of maps, sections and photographs.	Volcano and dykes/jelly and cream - radial dykes (ELI+)
Observation and investigation of igneous rocks to deduce the cooling history: • crystal size: coarse (>3 mm), medium (1- 3 mm), fine (<1 mm) • crystal shape: euhedral, subhedral, anhedral • texture: equicrystalline, porphyritic, vesicular, glassy, fragmental (tuff) • structure: pillow structure, aa/pahoehoe surfaces, columnar joints. Identification in hand specimen of the following igneous rocks from their composition, texture and other diagnostic features: • Silicic: granite • Mafic: gabbro, dolerite, basalt • Ultramafic: peridotite.	Unfair ‘build your own crystal’ race (ELI+) Why do igneous rocks have different crystal sizes? (ELI+) Building Stones 2 - Igneous rocks Rock grain cut out How can you tell which grains come from which rock? Urban fieldwork – the stories from materials, colours, lines and shapes: find out the stories told by materials used in building and for decoration. A rock is a time capsule – a message from the past: Bringing to life the extraordinary stories of ordinary rocks Picturing igneous rocks – 1 Visualise and draw igneous rocks from a verbal description Picturing igneous rocks – 2 Visualise and draw igneous rocks from a verbal description Building silicates: Simulating crystal size during the cooling of magma and during recrystallization in solid rock
c. Partial melting of rock at depth to form magma occurs in a number of different interplate and intraplate tectonic settings: • beneath divergent plate margins - partial melting of mantle rocks generates basaltic magma • near to convergent plate margins - partial melting of subducted oceanic lithosphere and overlying lithospheric wedge generates andesitic magma • in mantle plumes (hotspots) – partial melting of mantle rocks generates basaltic magma • in deeply buried lower continental crust during orogeny – melting and assimilation of crustal material generates granitic magma. Investigation of the role of rising convection cells in decompression melting. Investigation of global distribution of mantle plumes from maps.	Collapsing volcanoes - cauldron subsidence (ELI+) Hotspots (ELI+) A “mantle plume” in a beaker – but not driving plates Mantle plumes ‘yes’ – but convection currents driving plates, probably ‘No’ . Replacement for 86. Partial melting - simple process, huge global impact (ELI+) Partial melting model and real rock (ELI+) See how they run
d. Volcanic hazards result from: • blast/explosion • ash fall, pyroclastic flows (nuées ardentes) and gases	Eruption through the window When will it blow? – predicting eruptions

- lava flows - debris flows and mudflows (lahars). Investigation, using geological data from a wide variety of volcanic monitoring techniques (including ground deformation, gravity and thermal anomalies, gas emissions and seismic activity), of the risk of volcanic hazards and the extent to which they can be managed and controlled in order to reduce risk.	
e. The nature of the volcanic hazard is linked to the composition, viscosity and gas content of the magma.	Blow up your own volcano! Bubble-mania Best classroom eruption? Which type of classroom eruption best shows how volcanoes erupt?
f. Metamorphism involves mineralogical and/or textural change of pre-existing rocks in response to changes in temperature and/or pressure. Interpretation of the following metamorphic features using simplified geological maps and photographs: contact aureoles, metamorphic foliations.	Metamorphic aureole in a tin (ELI+) Metamorphism - that's Greek for 'change of shape' isn't it? Metamorphic processes: controlled by depth, temperature and pressure What factors control metamorphism?
g. Contact (thermal) and regional metamorphism produce distinctive mineralogical and textural changes: - non-foliated in contact metamorphism - foliation (slaty cleavage, schistosity and gneissose banding) in regional metamorphism. Identification in hand specimen of the following metamorphic rocks from their composition, texture and other diagnostic features: marble, metaquartzite, spotted rock, hornfels, slate, schist, gneiss.	Building Stones 4 - Metamorphic rocks Rock grain cut out How can you tell which grains come from which rock? Urban fieldwork – the stories from materials, colours, lines and shapes: find out the stories told by materials used in building and for decoration. A rock is a time capsule – a message from the past: Bringing to life the extraordinary stories of ordinary rocks Picturing metamorphic rocks - Visualise and draw metamorphic rocks from a verbal description

F2 Key Idea 3: Deformation results when rocks undergo permanent strain in response to applied tectonic stresses and can be interpreted using geological maps	
a. Rock deformation can be interpreted by reference to Hooke's Law: Simple stress - strain curves showing elastic/brittle and ductile/plastic behaviour; elastic limit, permanent strain and fracture point.	Squeezed out of shape Deformed Trilobites: Using fossils to estimate the distortion of rocks
b. Evidence of rock deformation includes dipping beds, folding, faulting and unconformities. Measurement and description of evidence obtained by sampling of rock deformation in the field (or from photographs). Use of simple calculations to establish the amount of deformation (percentage of crustal shortening).	*Opengeoscience* 2: tilted and folded rocks From folds to crustal shortening: visualising past processes by calculation Modelling unconformity – by hand: using your hands to demonstrate how unconformities form. What catastrophic natural processes affected your region in the geological past? Use the evidence in your local region to interpret dramatic geological events

Recognition and interpretation of structural features through study of photographs, diagrams, sections, geological maps and in the field.	Picturing tectonic structures – 1 faulting. Visualise and draw fault structures from a verbal description Picturing tectonic structures – 2 folding Visualise and draw fold structures from a verbal description
c. Dipping beds are the results of tectonic/gravity induced stresses, caused by plate movement, that distort beds from the horizontal.	
d. Folding results when compressional stresses exceed the yield strength of a rock. Recognition of fold elements: limb, hinge, axis, axial plane trace, fold symmetry (as a function of limb length), antiform, synform, anticline, syncline.	Banana benders Swiss roll surgery Modelling by hand 'when the youngest rock is not on top' Illustrating how rock sequences can have older rocks on top of younger ones Modelling folding – by hand: -using your hands to demonstrate different fold features Right way up or upside down? - modelling anti- and synforms by hand Use your hands to show how the beds in folds can be the right way up or inverted Visualising plunging folds - with your hands and a piece of paper Using your hands and folded/torn paper to show the patterns made by plunging folds The sliced Jelly Babies™ approach to understanding 3D geological maps: Use Jelly Babies™ cut at the dip angle to highlight structures on geological maps Mapping "structures" on the playing field An exercise in measuring strike and dip
e. Faulting results when applied compressional, tensional or shear tectonic stresses, caused by plate movement, exceed the fracture strength of a rock. Recognition of fault characteristics: • dip-slip: normal, reverse, thrust; throw - amount, relative movement of footwall/hanging wall • strike-slip: left/ sinistral, right/dextral fault displacement (= net slip).	Valley in 30 seconds - pulling rocks apart Himalayas in 30s Modelling Earth stresses with your hands - Hand modelling of compression, tension and shear in the Earth Modelling faulting – by hand: Using your hands to demonstrate different fault features
f. Unconformities represent a hiatus in the geological record resulting from a combination of Earth movements, erosion and sea level changes. Recognition of unconformities and their use in relative dating.	Filling the gap – picturing the unconformity *'abyss of time'?* Rocks from the big screen
g. The nature of outcrop patterns formed by the intersection of geological structures with a topographic surface are displayed on geological maps. Use of geological maps, block diagrams, boreholes, cross-sections and photographs to interpret the geology of an area. Construction of geological cross-sections from simplified geological maps.	See T2 Key Idea 1 for geological maps and models When are soft rocks tough, and hard rocks weak? A discussion about the toughness/resistance of rocks in different places Folds and faults with puff pastry and chocolate: understanding folds and faults in cross section and on a geological map Teaching geology to students with visual impairment (VI) - 2 Modifying visual resources for students who cannot see Picturing Landforms -1 Visualise and draw landforms from a verbal

	description Picturing Landforms -2 Visualise and draw landforms from a verbal description Picturing Landforms - 3 Visualise and draw landforms from a verbal description Picturing Landforms – 4: Mass Movement A: Visualise and draw landforms from a verbal description

Ordering the geological sequence of events in an area from the study of a simplified geological map and/or section.	

Topic F3: TIME AND CHANGE	
Key Idea 1: Study of present day processes and organisms enables understanding of changes in the geological past	
a. Much of the rock record can be interpreted in terms of geological processes that are operating today by applying the Principle of Uniformitarianism: the present is the key to the past. Investigation of the development of *uniformitarianism* and the *rock cycle model* over time and the contributions of James Hutton and William Smith.	Rock cycle at your fingertips Rock cycle in wax Rock cycle - laying out the rock cycle: product and process Rock cycle through the window Rock cycle: Not misunderstanding the rock cycle James Hutton - or 'Mr. Rock Cycle'? (ELI+) How long does it take? William Smith - 'The Father of English Geology' (ELI+) View to the future – and the past: Using a viewpoint or overview educationally 'Looking so far into the Abyss of Time' How to visualise the immensity of geological time…with a rope!
b. The study of modern environments enables an interpretation of the sedimentary rock record within the rock cycle model.	What was it like to be there – in the rocky world?
c. The basic unit of sedimentary geology is the *facies* which reflects the depositional environment: lithofacies, biofacies.	
d. Fossils are evidence of former life preserved in rocks. They provide information on the nature of ancient organisms and palaeoenvironmental conditions. Appreciation of the basic distinctions between the following fossil groups based on their hard parts. • brachiopods (marine): shell shape and symmetry, pedicle and brachial valves, foramen, hinge line, muscle scars • bivalves (marine/freshwater): shape and symmetry of valves, number and size of muscle scars, hinge line, teeth and sockets, gape, pallial line and sinus, umbones • cephalopods (marine): suture line, coiled and chambered shell • corals (marine): colonial, solitary, septa • trilobites (marine): cephalon, glabella, genal spines, eyes, thorax, number of thoracic segments, pygidium • graptolites (marine): stipes, thecae • plants (terrestrial): leaf, stem, root • trace fossils (tracks and trails, burrows, coprolites).	Ammonites: the ups and downs Who ate the ammonite? Fossil or not? How could I become fossilised? Running the fossilisation film backwards Trace fossils - burrows or borings Trail-making What was it like to be there? - bringing a fossil to life Darwin's 'big coral atoll idea': Picturing trace fossils and other strange shapes: Visualise and draw trace fossils and sedimentary structures from a verbal description Picturing Fossils -1 Visualise and draw fossils from a verbal description Picturing fossils – 2 Visualise and draw fossils from a verbal description What were the animals doing? Interpreting footprints and other marks in the sand
e. Fossil morphology is used to interpret function/mode of life: • bivalves (burrowers/non burrowers)	Curious creatures Fifty million years into the future Sea shell survival

• trilobites (benthonic/pelagic).	
f. Preservation can give rise to a wide range of fossil materials: actual remains, hard parts, petrification by mineral replacement (calcification, silicification, pyritisation), carbonisation, moulds/casts.	How could I become fossilised? From hard-boiled eggs to bog bodies An investigation into the effects of tannin and mild acid
g. Fossils accumulations may be preserved without appreciable transportation (life assemblages) or preserved after transportation (death assemblages), or as derived fossils re-deposited in later sediment. Analysis of modern and fossil assemblages to interpret the degree of transportation prior to burial.	
h. The fossil record is: • biased, in favour of marine organisms, with body parts resistant to decay, that lived in low energy environments, and suffered rapid burial • incomplete, as natural processes can distort or destroy fossil evidence (predation, scavenging, diagenesis, bacterial decay, weathering, erosion, metamorphism)	Shell shake - survival of the toughest

F3 Key Idea 2: Geological events can be placed in relative and absolute time scales	
a. Geological events can be placed in relative time scales using criteria of relative age: evolutionary change in fossils, superposition of strata, unconformities, cross-cutting relationships, included fragments, 'way-up' criteria. Interpretation of age relations of rocks and rock sequences using maps, cross-sections and in the field	Sedimentary structures - cross-bedding and ‘way-up’ Laying down the principles What is the geological history? What happened when?: sorting out sequences using stratigraphical concepts - Are the age-based stratigraphical concepts principles or laws? – and how do you use them? Photo dating’ Using photos to simulate the relative dating of the rock record.
b. Some rocks and minerals can be dated radiometrically to give an absolute age. This involves radioactive decay and the principles of radiometric dating; radioactive series and radioactive half-life; radiometric dating as exemplified by Potassium – Argon (^{40}K– ^{40}Ar), Samarium – Neodymium (^{147}Sm –^{143}Nd). Simple use of the principles of radiometric dating (decay rates and the half-life concept) to calculate the absolute age of a sample. Evaluation of the assumptions, accuracy and limitations inherent in the radiometric dating method.	Working out the age of the Earth - moving backwards as time moved forwards But how old is it? Investigating radioactive dating of rocks and minerals The origin of the Earth – at arm’s length. The age of the Earth – with a good stretch of imagination Counting to one million? Trying to imagine the enormity of geological time
c. Fossils are used in relative dating Observation and identification of appropriate morphological features and their changes through time:	

• graptolites - number and position of stipes, thecal shape in the Early Palaeozoic. • cephalopods - suture lines in the Late Palaeozoic and Mesozoic (goniatite, ceratite and ammonite).	
d. The factors contributing to good zone fossils for relative dating/correlation are: wide and plentiful distribution, ready preservation, rapid evolutionary change, a high degree of facies independence, easy identification of index fossils. • the utility of graptolites and cephalopods as zone fossils assessed in relation to the above factors.	
e. The geological column provides a means of: • placing geological events in their correct time sequence • defining the absolute age of some events.	Time-line in your own backyard Toilet roll of time Dating the Earth – before the discovery of radioactivity: Charles Lyell and Mount Etna, 1828
f. The rock record indicates changing conditions and rates of processes with long periods of slow change interrupted by sudden catastrophism causing mass extinctions through geological time. Interpretation of the ages of geological events using the geological column.	Sorting out the evolution of evolution headlines (ELI+) Extinction mystery What did kill the dinosaurs?

Topic F4: Earth structure and global tectonics	
Key Idea 1: The Earth has a concentrically zoned structure and composition	
	Craters on the Moon
a. The Earth has a layered structure: crust, mantle, outer and inner core. Each layer has a distinctive composition and/or rheological properties. Direct and indirect evidence is derived from meteorite (stony, iron) compositions, mantle xenoliths, mean density calculations and geophysical measurements (seismology, geomagnetism, gravity, conductivity). Analysis of seismological evidence for the internal structure of Earth: P and S body waves, surface waves, time-distance curves, shadow zones, velocity-depth models of Earth structure, density distribution with depth.	Merry waves - all year round (ELI+) Bouncing, bending, breaking (ELI+) From clay balls to the structure of the Earth (ELI+) Core activity (ELI+) Journey to the centre of the Earth - on a toilet roll Waves in the Earth 1 - the slinky simulation (ELI+) Waves in the Earth 2 – human molecules Bauble Quiz The slinky seismic waves demo Using slinkies to show how earthquakes produce P-, S- and surface waves Shadowlands Simulating the effect of the Earth's core on earthquake waves Chocolate Plates: Simulating the properties of a lithospheric plate Magnetic Manchester: Measuring changes in magnetic declination to investigate the Earth's core

b. The crust is a thin layer of distinctive composition overlying the mantle; continental and oceanic crust can be recognised and distinguished by their differing thicknesses, composition and structure. Analysis of ocean drilling data to re-interpret the Mohorovičić discontinuity (Moho) at the base of the crust (e.g. Joides Resolution 360).	Isostasy – 1 Modelling the state of “balance” of the Earth’s outer layers Isostasy - 2 “Bouncing back” after the ice UPDATE: Recent research in plate tectonics. Follow the *Joides Resolution* research ship at sea.

Simple analysis of geomagnetic evidence for core composition and processes. Interpretation of geophysical data on crustal structure (seismic, gravity, magnetic) from continental and oceanic areas.	

F4 Key Idea 2: The Earth’s internal heat is the underlying cause of lithospheric plate motions that control global geological processes	
	Plate riding (ELI+) Plate tectonics through the window (ELI+) Frozen magnetism (ELI+)
a. The uppermost part of the mantle and the overlying crust form a rigid outer shell of the Earth known as the lithosphere, forming tectonic plates, underlain by a weaker upper mantle zone known as the asthenosphere. The asthenosphere is evidenced by the seismological low velocity zone (LVZ).	From an orange to the whole Earth
b. The lithosphere consists of several plates in relative motion. Three types of plate boundary are recognised; divergent, convergent (involving subduction) and conservative. There is a relationship between seismicity, volcanicity and plate boundaries.	Continental split - the opening of the Atlantic Ocean Continents in collision (ELI+) Geobattleships Mars™ margins – diverged, converged and transformed Modelling plate margins with a Mars™ Bar – apart, together and side by side
c. Forces driving plates are a matter of current debate involving thermal convection of the mantle together with gravitational forces and ocean lithosphere density differences at subduction zones. Evaluation of the possible mechanisms for plate movement (role of mantle convection, slab pull, ridge push).	What drives the plates? Faults in a Mars™ Bar Pulling apart a Mars™ Bar to model a divergent plate margin Mars™ margins – diverged, converged and transformed Modelling plate margins with a Mars™ Bar – apart, together and side by side All models are wrong’ – but some are really wrong: plate-driving mechanisms Many textbook diagrams of plate-driving forces have arrows in the wrong places. A “mantle plume” in a beaker – but not driving plates Mantle plumes ‘yes’ – but convection currents driving plates, probably ‘No’. Replacement for 86. What drives the plates? – the evidence. Examine the evidence for the different plate tectonic driving mechanisms. What drives the plates? in slab pull, what is it that pulls? ? in slab pull, what is it that pulls? Understanding how slab pull works through examining the data. What drives the plates? Modelling slab pull Modelling and discussing the slab pull plate-driving mechanism in the classroom.

Investigation of how the plate tectonics paradigm developed over time, from continental drift, through active mantle convection carrying passive tectonic plates, to modern theories of the causes of plate movement (slab pull and ridge push).	Earth time jigsaw puzzle Wegener's 'Continental drift' meets Wilson's 'Plate tectonics' (ELI+) Wandering continents What evidence enables us to reconstruct the ancient supercontinent of Pangaea?
Interpretation of the evidence for plate tectonic theory from: • direct measurement – ocean floor drilling, relative movement using GPS • global maps of the distribution of continents, volcanoes, earthquake epicentres/foci, ocean trenches and ridges, orogenic belts and palaeoecological /palaeoenvironmental zones. • seismic tomography • an investigation of the geomagnetic/geoelectrial properties of rocks and minerals. • geothermal data (hot spots, heat flow).	Which is the fastest spreading oceanic ridge? A map-based activity to find the most active oceanic spreading ridge UPDATE: Recent research in plate tectonics What do the top and bottom of a tectonic plate look like? Questions to test understanding of plate tectonic processes Sounding the Pacific Ocean: An echo sounder traverse of the eastern Pacific. Marie Tharp: 'The valley will be coming up soon' - Bruce Heezen: 'What valley?' 'A woman scientist in a man's world' – what was it like? Marie Tharp: 'The valley will be coming up soon'. Bruce Heezen: 'What valley?' 'A woman scientist in a man's world' – what was it like? Laser Quest 1 – below the waves Seeing evidence for plate tectonics beneath the oceans - using echo sounding Laser Quest 2 – above the waves Seeing evidence for plate tectonics beneath the oceans - using satellites Mapping Magnetic Anomalies Modelling the palaeomagnetic evidence for plate tectonic boundaries on the ocean floor
d. Some rocks contain a record of the direction of the Earth's magnetic field at the time of their formation, known as remanent magnetism. This is linked to ferromagnetism in some iron minerals and their Curie temperatures.	Frozen magnetism (ELI+) Magnetic Earth (ELI+) Why won't my compass work on the other side of the Equator? (ELI+)
e. Palaeomagnetism can be used to determine changes of latitude as different continents moved through geological time, indicating continental drift. Ocean floor magnetic anomalies indicate sea floor spreading.	Did the continents move for you? (ELI+) Magnetic stripes (ELI+) Recipe for a magnetic Earth and a magnetic detector - Using a stress ball and small magnet, with a needle and thread to model magnetic Earth Hands on magnetic stripes: Demonstrating how oceanic ridge magnetic stripes form with several pair of hands When did the poles 'flip'? Simulating how the Earth's Geomagnetic Polarity Time Scale was established.
f. The various elements of the rock cycle may be linked directly to plate tectonic processes: • igneous - basaltic magmatism at oceanic spreading centres; basaltic and andesitic magmatism at convergent margins; granitic magmas in orogenic belts • sedimentary - erosional processes and depositional environments influenced by tectonic movements • regional metamorphism in subduction zones and orogenic belts at plate boundaries.	The deep rock cycle explained by plate tectonics: deformation and metamorphism - A model showing how plate tectonics can explain metamorphism and rock-deformation.

Topic G1 : ROCK FORMING PROCESSES	
Key Idea 1: The generation and evolution of magma involves different processes	
a. Igneous rock composition at interpolate and intraplate settings depends on: • origin of the parent magma (mantle or crust) • magma evolution: Differentiation and fractionation (continuous and discontinuous reaction series - Bowen); gravity settling to give cumulates • magma contamination: incorporation of rock material (xenoliths); magma mixing, during rise and emplacement, leading to change of composition and physical properties (enclaves).	

Evaluation of the role of temperature, pressure and water content in determining the melting points of rocks. Simple calculation of depth of formation of granite magma by crustal melting through interpretation of graphs showing continental geotherm and melting temperatures of wet and dry lower crustal material. Calculation of the age of a mineral sample using the decay rate equation $N = N0e-\lambda t$	
b. The substitution of one element for another in the crystal structure of a mineral depends upon atomic radius and valency; solid solution as exemplified by olivine and plagioclase feldspar. Investigation of magma crystallisation and differentiation processes using phase diagrams (plagioclase feldspar, olivine).	
c. The formation of magma chambers under ocean ridges and rises can be interpreted from models. Analysis of ocean survey data to investigate current models of how oceanic ridges (particularly mid-ocean ridges - MORs) are formed (e.g. RRS James Cook -2016).	

G1 Key Idea 2: The mineralogy and texture of metamorphic rocks are determined by the composition of the parent rock and the conditions of metamorphism	
a. Igneous and sedimentary rocks contain minerals that are stable or metastable at the temperature and pressure of their formation. Changes in temperature and/or directed stress over time lead to the growth of new minerals with different stability fields. Simple analysis of phase diagrams showing stability fields of selected metamorphic minerals: kyanite/ sillimanite/andalusite. Analysis of simple pressure - temperature - time paths involved in contact and regional metamorphism.	
b. Mineralogical changes during metamorphism depend on the composition of the parent rock and the temperature/pressure field.	

c. Contact and regional metamorphism of mudstone/shale lead to the growth of new minerals indicative of the type and grade of metamorphism: low to high grade metamorphism.	
d. Contact, regional and dynamic metamorphism result from different pressure/temperature conditions and produce characteristic textural changes associated with recrystallization, ductile flow and shear deformation. Study of diagrams/photomicrographs to identify and analyse the following metamorphic textures: granoblastic; porphyroblastic; mylonitic.	

G1 Key Idea 3: Sedimentary processes can be understood using scientific modelling	***See also Topic F2***
a. Sedimentary processes which are infrequent and/or difficult to observe (e.g. turbidity currents) can be understood and explained using scientific models. Application of the Hjulstrom graph.	Atmosphere and ocean in a lunchbox - A model for all pupils – of hot, cold and cloudy density currents Exploring current flows through straits: Testing the L. F. Marsili model of Bosphorus currents (1680)
b. The distribution of environments represented by rocks in a vertical stratigraphic column is related to the distribution of those environments laterally (Walther's Law); marine transgressions and regressions, diachronous stratigraphic boundaries. Application of Walther's Law to extend interpretation from two-dimensional data (borehole logs, cliff sections, graphic logs) to three-dimensions.	Walther's law of sedimentation – teaching it the LegoTM way: How does a relative rise in sea level affect a vertical sequence of sediments? Walther's law of sedimentation – teaching it the LegoTM way Part 2: How does a relative fall in sea level affect a vertical sequence of sediments?

G2 ROCK DEFORMATION	
G2 Key Idea 1: Geological structures are formed when rock material undergoes deformation	*See also Topic F2 Key Idea 3*
a. The nature of rock deformation is determined by the competence of the parent rock and conditions during deformation (temperature, confining pressure, strain rate). Recognition of the differences in deformation of competent and incompetent rocks.	
b. Fold characteristics; amplitude, wavelength, interlimb angle (open, tight, isoclinal), axial plane attitude (upright, inclined, overturned, recumbent), plunging folds.	From folds to crustal shortening: visualising past processes by calculation (ELI+) Himalayas in 30 seconds!

Identification of plunge direction (of axis) and axial planar cleavage.	Modelling by hand 'when the youngest rock is not on top' Illustrating how rock sequences can have older rocks on top of younger ones Modelling folding – by hand: -using your hands to demonstrate different fold features Right way up or upside down? - modelling anti- and synforms by hand Use your hands to show how the beds in folds can be the right way up or inverted Visualising plunging folds - with your hands and a piece of paper Using your hands and folded/torn paper to show the patterns made by plunging folds. The sliced Jelly Babies™ approach to understanding 3D geological maps: use Jelly Babies™ cut at the dip angle to highlight structures on geological *maps*
c. Fault type is determined by the orientation of the principal stresses. Technical terms to describe fault elements: slickensides, fault gouge, fault breccia. Analysis of the relationship between fault type (normal, reverse/thrust, strike-slip) and the orientation of the principal stress components (σ max, σint, σmin).	Fluids, friction and failure Modelling Earth stresses with your hands Hand modelling of compression, tension and shear in the Earth Every rock tells a story: Reading the rock history from an exceptional specimen of slate
d. Structural reactivation: earlier-formed faults can be reactivated during later tectonism; folds may be refolded. Structural inversion: reactivation of normal faults in compression or reverse faults/thrusts in extension. Recognition of evidence for fault reactivation on geological maps, cross-sections, diagrams and photographs	*See Topic T2. Geological Map Applications*
e. The nature of outcrop patterns formed by the intersection of geological structures with a topographic surface are displayed on geological maps. • Calculations involving measurements of: • true bed thickness • vertical bed thickness • width of outcrop • angle of dip.	Do-it-yourself dip and strike model (with DIY clinometer) (ELI+) Mapping "structures" on the playing field An exercise in measuring strike and dip *See also Topic T2*
	Building Stones 1 - a resource for several ELI activities Building Stones 2 - Igneous rocks Building Stones 3 - Sedimentary rocks Building Stones 4 - Metamorphic rocks

	Roadstone - which rock? Testing rocks 1 - bouncing back Will my gravestone last? Fluids, friction and failure

G3 PAST LIFE AND PAST CLIMATES	
G3 Key Idea 1: Fossils provide evidence for the increasing diversity of life through geological time	
a. The fossil record provides evidence of changes in floras and faunas through geological time and the development of higher life forms: • Precambrian life: life possibly evolved early in Earth history (3.8 billion years ago). The Ediacaran fauna represents the oldest diverse set of multicellular, soft bodied organisms (565 Ma) • The Cambrian Explosion: the development of mineralised skeletons led to a wide variety of advanced marine invertebrates by the early Cambrian • Life in the ocean diversified in stages identified by separate fauna: a basic understanding of the difference between Cambrian, Palaeozoic and modern faunas • The Phanerozoic was marked by the migration of organisms onto the land during the Palaeozoic. Vertebrate development of amphibians from fish, reptiles from amphibians and mammals and birds from reptiles. Colonisation by of the land by plants. Interpretation of evolutionary diagrams. Analysis of the possible causes of faunal diversification at the Precambrian-Cambrian boundary. Interpretation of simple diversity curves (Sepkoski’s curves). Analysis of the morphology of fossil vertebrates (including dinosaurs) to interpret function/mode of life.	Dinosaur death - did it die or was it killed? Dinosaur in the yard How to weigh a dinosaur Mary Anning - Mother of Palaeontology Meeting of the dinosaurs - 100 million years ago Let’s weigh that dinosaur! How can a plastic model reveal the mass of an actual dinosaur?
b. Diversity increased through the Phanerozoic punctuated by many declines caused by mass extinction events. Mass extinctions may result from a variety of causes including: • asteroid impact (Alvarez)	The pattern of continents/oceans versus the pattern of life on Earth

- large scale volcanicity (flood basalts) - changes in land/sea levels - rapid climate change. Evaluation of contrasting hypotheses regarding mass extinctions.	
c. Mass extinctions are exemplified by the end-Permian (P-T) and Cretaceous-Paleogene (K-Pg) boundary events. .	
d. There are alternative interpretations of evolutionary patterns based on the fossil record. Gradual change (gradualism) vs stability interrupted by sudden change (punctuated equilibrium). Evaluation of alternative interpretations of evolutionary patterns.	

G3 Key Idea 2: A combination of global factors contributes to climate change through geological time	
a. Long-term changes to the global climate, composition of the atmosphere, sea level and distribution of the continents are recorded in the Phanerozoic rock record. The J. Tuzo Wilson Cycle provides a framework for understanding these long term changes. Analysis of *present day* oceanic and atmospheric circulation in relation to climatic effects. Analysis of data used to determine *past* climatic regimes.	Climate on arrival: If you suddenly arrived somewhere – what would tell you what the climate was like? Lost at sea – the amazing journeys of rubber ducks around the world: Studying ocean currents following the Friendly Floatees ocean spill Why coastal regions enjoy a milder climate than landlocked areas Modelling the ocean's influence on climate by comparing the heat capacity of water and soil
b. Changes in the atmospheric composition of greenhouse gases (especially CO_2 and methane) result from natural processes (volcanic activity, rock weathering, warming of methane hydrates) throughout geological time. Evaluation of the contribution of naturally produced CO_2 and methane to climate change with time.	Is the greenhouse effect happening outside today? A classroom discussion to consolidate understanding about the greenhouse effect Ocean acidification – The other CO_2 problem: See how acidified water affects calcareous marine organisms Greenhouse effect in a bottle How to simulate the effect of increased CO2 level on Earth's temperature See Appendix
c. There have been climate changes throughout geological time. The current rate of change appears to differ from those in the past. Analyses of graphs showing different rates of climate change.	Modelling tipping points – by hands**:** Demonstrating tipping points in the Earth's system with the hands of three people What could we measure to find out if climate change is happening here? Finding the Earth in the UN Sustainable Development Goals Map for yourself the areas where Earth studies are linked to the UN SDGs

d. The Anthropocene is a proposed epoch that began when human activities changed the Earth’s surface environment on a scale comparable with the major events of the geological past. There is currently a lack of consensus for the proposed epoch. Evaluation of the arguments in the debate for the inclusion of the Anthropocene as a new epoch.	What might be the marker for the ‘golden spike’ at the end of the Anthropocene?

G3 Key Idea 3: Evidence for global climate change is interpreted from the geological record and the geochemistry of rocks	
a. Evidence for global climate changes can be interpreted from both the geological record and the isotope geochemistry of ocean-floor sediments. Investigation of the evidence for climatic extremes in the rock record.	The oxygen isotope sweet simulation Demonstrating how the oxygen isotope proxy records past Earth temperatures ‘Earth’s oxygen thermometers’ Simulating how ocean sediment and continental ice cores record past changes in Earth’s temperatures.
b. The fossil record provides evidence of different climatic zones, as exemplified by: • land plants • corals	
c. Sedimentary sequences provide evidence of palaeoenvironments related to particular climatic zones. • Ancient icehouse deposits (e.g Carboniferous). • Tropical greenhouse deposits (e.g. Cretaceous).	
d. Oxygen isotope ratios ($^{18}O/^{16}O$) in fossil shells are indicative of the temperature of ancient ocean waters. Simple analysis of oxygen isotope curves.	Interpret Earth temperatures from simulated deep-sea and ice cores -Using sweets to simulate oxygen isotope ratios in cores
e. The “Snowball Earth” hypothesis proposes that the Earth's surface became entirely or nearly entirely frozen at least once, sometime earlier than 650 Ma. Assessment of the validity of the evidence for the “Snowball Earth” hypothesis in Neoproterozoic rocks.	

Topic G4 : EARTH MATERIALS AND NATURAL RESOURCES	
Key Idea1: Geological processes lead to the concentration and accumulation of natural resources in deposits that can be exploited; economic deposits can be concentrated by igneous and sedimentary processes	
a. Processes of formation of metalliferous ores.	Smelter on a stick (ELI+)

- Igneous associations of ores - magmatic segregation, hydrothermal activity - Sedimentary associations of ores - placer deposits; residual deposits; precipitated deposits. Geological map interpretation (ore body geometry, field relations); section-drawing through ore bodies. Geological map interpretation; section drawing through industrial mineral deposits.	Gold prospectors Hydrothermal mineralisation - interactive (ELI+) Riches in the river Essential Minerals for the Green Revolution – 1 Lithium An element which is pulling more than its weight in the world Essential Minerals for the Green Revolution – 2 Copper An element for which the demand is increasing rapidly Essential Minerals for the Green Revolution – 3 Rare Earth Elements Vital components in modern technology Essential Minerals for the Green Revolution – 4 Graphite From a pencil to the electric car! Essential Minerals for the Green Revolution -Cobalt Mined by children Essential Minerals for the Green Revolution – 6 “The Three Ts” Tin, Tungsten and Tantalum Essential Minerals for the Green Revolution – 7 Gold An essential mineral – or is it? Essential Minerals for the Green Revolution – 8 Critical Minerals Essential mineral – critical mineral: what is the difference? Essential Minerals for the Green Revolution – 9. Critical Minerals for the USA Why are certain minerals of such importance to the USA?
b. Processes of formation of non-metallic minerals of economic importance: china clay.	
c. Formation of sedimentary deposits of economic importance as "bulk minerals" for aggregate: sand and gravel.	
d. Origin of hydrocarbons and coals: hydrocarbons and coals result from the thermal alteration of organic material due to burial. - Hydrocarbons: source rocks; sediment burial and the temperature and pressure conditions of oil and natural gas formation. - Coal-forming environments; peat, lignite, bituminous coal, anthracite; coal rank. Simple analysis of maturity: depth (temperature) graphs showing oil and natural gas windows. Identification of coal types. Simple assessment of reserves (e.g. tonnage of coal in a given area).	Where shall we drill for oil? Fracking: Recipe for the perfect fracking fluid Where does offshore oil come from? What is/are the least bad option(s) for plugging the future global energy gap?

G4 Key Idea 2: Permeable rocks offer pathways for oil and gas migration; highly porous rocks can act as natural reservoirs for underground supplies of oil and gas	

a. Porosity and permeability of rock and sediments affects the presence, distribution and migration of fluids (water oil and natural gas): primary/secondary porosity in rock; factors that affect porosity and permeability. Analysis of rock textures in terms of porosity and permeability (grain size, shape, packing, sorting; cementation); primary and secondary porosity.	From rain to spring: water from the ground The space within – the porosity of rocks Limestone springs – the wells of Wells: Modelling the underground flow of water through limestone passages to springs
b. Fluid flows in rocks and sediment can be modelled using Darcy's Law. Application of Darcy's Law to model fluid flow: $Q = -\kappa A\,\underline{(h2 - h\ 1)}$	Water pressure - underground (ELI+)

(L)	
c. Oil and gas migration are controlled by geological factors: migration paths - relative buoyancy of oil and natural gas; structural and stratigraphic traps for hydrocarbons; reservoir rocks and cap rocks. Analysis of geological cross-sections through oil and natural gas bearing structures.	Make your own oil and gas reservoir Trapped! Why can’t oil and gas escape from their underground prison? Blue Hydrogen – the fuel of the future? Could “blue” hydrogen be produced and used here?
d. The characteristics of subsurface geology which control the flow of groundwater (hydrogeology) include confined and unconfined aquifers, aquicludes, aquitards, the water table, piezometric surfaces, cones of depression and recharge zones. Analysis of the controls on groundwater quality which result from geochemistry (carbonates and sulfates), aquifer filtration, residence time and sources of pollution.	Limestone springs – the wells of Wells: Modelling the underground flow of water through limestone passages to springs

G4 Key Idea 3: A wide range of prospecting techniques can be employed to explore for mineral resources	
a. Techniques used to prospect for mineral resources. • geophysical surveying – gravity (Bouguer), seismic, magnetic, electrical. • geochemical prospecting – river water, river sediment and soil sampling. Each method has particular applications and limitations. Geological map interpretation; simple analysis of geophysical and geochemical data related to mineral exploration. Selection of appropriate geophysical methods for different mineral searches, depending upon the geometry and physical properties of the target body. Interpretation of seismic reflection sections to identify potential oil and natural gas-bearing structures. Construction of geological cross-sections from borehole data, including dating and correlation using microfossils.	Modelling remote sensing geophysics (ELI+) Electrical ground probing
b. Microfossils are used for correlation in prospecting for oil and natural gas.	

7.2.3 Whole basin facies analysis	

7.2.3 (a) the principles of basin analysis to the integration of the sedimentology and palaeontology of the Welsh basin: To include: • deep sea turbidites and shelf deposition • reef limestones • use of: trilobites, corals and graptolites as zone fossils. To include: trilobites, corals and graptolites as zone fossils. (i) the geological settings and sedimentary conditions in the Welsh Basin, throughout the Cambrian, Ordovician and Silurian periods. (ii) how palaeoenvironments in the Welsh Basin can be determined by the analysis of facies (sediments and fossils) (iii) the zonation of the Welsh Basin using zone fossils. 7.2.3 (b) the principles of basin analysis in relation to the Jurassic rocks which crop out across the United Kingdom (in a local context): (i) the evidence for the geological setting and cyclical sedimentation in shallow seas (ii) facies analysis of the sediments formed in the basin (sedimentary structures, sediment type and fossils) to determine palaeoenvrionments (iii) the zonation and correlation of the Jurassic Period using ammonites and belemnites. To include: • the deposition of shales, limestones, siltstones, sandstones and ironstones • the use of burrows and other trace fossils to determine palaeoenvironments • key common macrofossils (ammonites, belemnites and bivalves) • marine reptiles (ichthyosaurs and plesiosaurs) and flying vertebrates (pterosaurs) • use of ammonites and belemnites in determining palaeoenvironments. 7.2.3 (c) practical investigation integrating field geology and secondary data (e.g. geological maps, seismic data, well logs, fossils) to understand the palaeoenvironments and geological history within the context of a basin wide study.	Trace fossils – burrows or borings: what evidence do living organisms leave behind in rocks?

GEOLOGICAL THEMES

T1 Geohazards
T2 Geological map applications
and one option topic from

T3 Quaternary geology
T4 Geological evolution of Britain
T5 Geology of the lithosphere

Topic T1 : GEOHAZARDS	
Key Idea 1: Natural geohazards have a worldwide impact on human populations including in the British Isles	Which natural hazards could damage the area where you live? How safe is your home area? (*And for topics below*)
a. Seismic hazards. • There is a relationship between earthquakes and active fault zones. • The magnitude of an earthquake event is measured on the Moment Magnitude scale (MW). The intensity of earthquake damage around an event is measured on the modified Mercalli scale and is related to earthquake size, depth, distance, local ground conditions and building standards. • Seismic hazards include ground shaking, liquefaction. • Tsunamis can cause devastation in coastal areas following an undersea earthquake (landslide or volcanic eruption). Analysis of geological data from appropriate case studies of each the following: • a major earthquake • a mass movement event to compare and contrast the nature of the geological hazards. Investigation of the factors that affect the impact of earthquakes and mass movements.	Merry waves - all year round (ELI+) Earthquake in your classroom Earthquake through the window - what would you see, what would you feel? Jelly/biscuit modelling of how earthquake waves amplify and devastate Quake shake - will my home collapse? Shaken but not stirred? Surviving an earthquake Geobattleships (ELI+) Spaghetti quakes Why are big earthquakes so much more destructive than small ones? Krakatoa - The balloon goes up at Krakatoa Tsunami alert! Run for the hills or stay by the sea? Tsunami through the window - what would you see, what would you feel? Tsunami! What controls the speed of a tsunami wave? Earthquakes in art - developing a scientific report based on evidence in historic paintings Making waves: a storm in a teacup? Three ways to make waves in a container of water: wind, earthquake and impact
b. Mass movement hazards. • The mechanism and triggering of rock avalanches, landslides and debris flows are linked to angle of slope, lithology, weathering, load, groundwater regime, rainfall, ground vibration, vegetation cover.	Danger - quicksands! Failing slopes Landslide through the window - what would you see, what would you feel? If a sedimentary bed were laid down outside now – what would it be like? A discussion of beds and catastrophic processes Coastal erosion: What controls the form of a coastline and the steepness of its cliffs?
c. The British Isles is prone to local natural geohazards at different scales associated with: earthquakes, landslides, shrinking and swelling clays and subsidence (including sink holes). Analysis of the causes and effects of geohazards in the British Isles from appropriate data sets.	Testing rocks 2 - ‘Splat!’ Testing rocks 3 - that shrinking feeling Sink hole! Landslide danger – and climate change: Case studies of how landslides work and the likely effects of climate change Picturing Landforms – 5: Mass Movement B Visualise and draw landforms from a verbal description

d. There is evidence that significant tsunamis have affected the British coast in the recent geological past.	

T1 Key Idea 2: Geohazard management attempts to predict and manage hazardous geological events with only limited success	
a. Geohazard and risk are intimately linked. • Geohazard: the probability of a change in the geological environment of a given magnitude within a specific time period in a given area. • Risk: the consequent threat of loss of life or damage to property and infrastructure.	
b. The risk assessment of geohazards involves an analysis of: • the nature of the hazard • the probability of occurrence and the return period of the hazard • communication of the risk to the vulnerable population.	
c. Attempts to predict earthquakes include monitoring changes in: seismic activity, groundwater levels and pressure, ground deformation (creep meters, strain meters, tilt meters), radon gas emissions and electrical resistivity. An investigation of the monitoring of: • a major earthquake • a mass movement event evaluating the level of success in hazard prediction.	Earthquake prediction - when will the earthquake strike? Party time for volcanoes! (ELI+) Take a 'Chance' on the volcano erupting (ELI+) When will it blow? - predicting eruptions Slip-sliding away How does monitoring fault creep help to forecast earthquakes?
d. Sites of potential slope failure can be monitored by: • ground levelling and surveying; monitoring of micro-seismic events and borehole distortion; ground deformation (creep, strain, tilt) and groundwater pressures • Use of electronic distance measurement (EDM), satellite and GPS techniques.	
e. The destructive effects of earthquakes and mass movements can, to some extent, be managed and controlled by engineering geology applications. Earthquakes: reducing of the impact of ground accelerations; aseismic building design; tsunamis defences. Mass movement: slope stabilisation methods, drainage control, retaining structures.	

T1 Key Idea 3: Engineering activities can have a major impact on the natural environment	
a. Extraction of geological raw materials and economic storage of waste products involves interference with the surface and/or subsurface environment.	Jigging Quarry through the window - what would you see, what would you not see? From rain to spring: water from the ground -Demonstrating how water flows through the ground – and how it can be used and polluted

• Quarrying and mining. Problems associated with the extraction of rock and minerals – stability of working faces, rock falls, ground subsidence, flooding, surface/groundwater pollution and waste tipping. Analysis of the methods of extraction of geological raw materials to identify potential environmental problems and the ways by which these may be minimised. • Waste disposal. Problems of ground contamination, including groundwater pollution and methane gas production, can be ameliorated by good geological site selection and engineering practice. There are special problems with the disposal of highly toxic chemical and radioactive waste. Analysis of landfill engineering data for the disposal of domestic waste or underground sites for the disposal of highly toxic chemical and radioactive waste. • Contaminated land. Problems with the management and remediation of industrial brownfield sites associated with toxic chemical materials, ground instability, subsidence and groundwater pollution. Analysis of the issues associated with the remediation of one industrial brownfield site.	Energy from buried waste: Landfill gas Nuclear waste disposal: Investigating geological disposal facilities (GDFs)
b. Civil engineering work should take account of geological factors to avoid: • problems of ground instability associated with weathering, dip of strata, folding, faulting, rock cleavage, joint patterns and fracture density Simple analysis of rock slope stability involving friction angle and orientation of rock discontinuities. Analysis of the suitability of sites using a variety of geological and geotechnical data. • interference with the hydrological system: pore water pressure, surface and underground drainage (porosity, permeability, water table, aquifers) • radon gas - sources and pathways to surface, surface geology of high-risk areas.	Failing slopes - Modelling how rock cliffs and slopes can collapse Storing gas underground: What can we store? How can we do it? How will it help? Matching supply and demand using stored water: Pumped storage hydroelectric schemes – just-in-time power Correlation between boreholes Illustrating uncertainty in ground investigations using LegoTM
c. In building major structures geological factors and geological rock properties must be taken into account (e.g. dams and reservoirs, cuttings and tunnels, buildings).	Dam burst danger Flood through the window Testing rocks - 1 bouncing back - Testing the strength of rocks

	Harnessing the power of waves: investigating the development of wave power

Topic T2 : GEOLOGICAL MAP APPLICATIONS	
Key Idea 1: Outcrop patterns on geological maps can be used to identify and interpret structural elements	
a. Outcrop patterns of dipping strata and faults in relation to topography: direction of closure of V-shaped outcrops in valleys as an indication of dip direction; close parallelism of geological boundaries and topographic contours as a sign of near horizontal dip; linear geological boundaries crossing topographic relief as an indication of steep dip. Interpretation of relationships between structural features, outcrops and topography on geological maps. Identification of fold types using outcrop patterns on geological maps. Identification of fault types and measurement of displacements using offsets of geological boundaries across faults. Identification of unconformities based on field relationships displayed on geological maps. Analysis of the 3D nature of geological maps and cross-sections using block diagrams and/or GIS systems (including Google Earth^{TM}).	Geological mapwork from scratch 1: a conical hill (ELI+) Geological mapwork from scratch 2: valley with simple geology (ELI+) Geological mapwork from scratch 3: valley with dipping geology (ELI+) Geological mapwork from models 1: plain with simple geology (ELI+) Geological mapwork from models 2: cuesta with simple geology (ELI+) Geological mapwork from models 3: valley with horizontal floor (ELI+) Geological mapwork from models 4: sloping ridge and valley (ELI+) Geological mapwork from models 5: folded geology on block models (ELI+) Geological mapwork from models 6: plain with faults in the direction of dip (ELI+) Geological mapwork from models 7: plain with faults parallel to the outcrop of the beds Geological mapwork from models 8: plain with different types of fault (ELI+) Geological mapwork: using surface geology to make a geological map (ELI+) The do-it-yourself dip and strike model

T2 Key Idea 2: Geological maps contain information relevant to a wide range of geological applications	
a. Geological maps provide an essential database of detailed information about the distribution of rocks at the surface that can be used to interpret or predict subsurface geological conditions. Use of geological maps at various scales to identify from outcrop patterns and other data on geological maps: • conformable and unconformable sedimentary formations • metamorphic sequences and igneous bodies (and any associated metamorphic effects)	*Opengeoscience 1*: igneous intrusions and lavas *Opengeoscience 2*: tilted and folded rocks Teaching geology to students with visual impairment (VI) Modifying block models to teach map-work to students who cannot see Mapping “structures” on the playing field An exercise in measuring strike and dip

• structural features.	
b. Geological maps provide an essential database for geological applications: Use of geological maps at various scales to: • design of construction projects: assess the potential of surface sites for a range of engineering projects on the basis of the prevailing geology • identification of geological hazards: identify geological hazards (landslides, subsidence) at defined surface sites on the basis of the prevailing geology • location of resources - groundwater, fossil fuels; alternative energy sources: interpret subsurface geology in connection with groundwater (water table, springs, aquifers, artesian wells), coal, oil, natural gas and geothermal energy • identification of environmental issues from extraction of these resources: identify the environmental issues specific to extraction of resources from the map area • assessment of suitability for sustainable waste disposal or brownfield remediation: assess the suitability for sustainable waste disposal/contaminated land remediation in a given area.	Rock power: geothermal power simulations (ELI+) Deep geothermal power from ‘hot dry rocks’: an option in your area? A discussion of potential for extracting ‘hot dry rocks’ geothermal energy locally Matching supply and demand using stored water Pumped storage hydroelectric schemes – just-in-time power Make your own aquifer – 1 with sponges A clean way to demonstrate water in pores in rocks Make your own aquifer – 2 The London Basin Model the aquifers in the London Basin with sponges

Option T3: QUATERNARY GEOLOGY	
Key Idea 1: A combination of global factors contributes to climate change through geological time	
a. Milankovitch cycles are regarded as a contributory cause of climatic fluctuations during the Quaternary.	The Earth and Milankovitch cycles – by hand Modelling the Earth’s squashed orbit, tilt and wobble using your hands
b. The distribution of continents and mountain belts affects oceanic and atmospheric circulation, influencing past and present global climate.	Atmosphere and ocean in a lunchbox: A model for all pupils – of hot, cold and cloudy density currents

Analysis of present day oceanic and atmospheric circulation in relation to climatic effects.	
c. The switch from a global greenhouse to icehouse climate is moderated by the efficiency of heat transfer from equatorial to polar latitudes; possible influence of the opening of the Drake Passage and rise of the Himalayan mountains.	

T3 Key Idea 2: The wide range of Quaternary deposits and landforms provides a fragmentary record of former glacial and interglacial stages in Britain	
a. The wide range of glacial, periglacial, fluvioglacial and interglacial deposits and landforms in Britain provides an incomplete record of climatic fluctuations and varying sedimentary environments. Information may be deduced on ice sheet dimensions and ice movement patterns.	Evidence from the deep freeze Ice-thickness from scratch: visualising past processes by calculation (ELI+)
b. There is geological evidence for glacial and interglacial stages, and for shorter-term climatic cycles superimposed on the dominant pattern of glacial and interglacial stages.	
c. There is a link between continental ice sheets and sea level: low sea levels during glacials, high sea levels during interglacials. Isostatic response to ice loading and unloading. Analysis of evidence for Quaternary sea level changes (e.g. raised beaches, drowned valleys). Simple calculations of amount of rebound caused by ice unloading. Analysis of evidence for relative changes in sea level caused by ice loading.	Isostasy – 1: Modelling the state of “balance” of the Earth’s outer layers Isostasy – 2: “Bouncing back” after the ice. Isostasy - “Hooray and up she rises!” Melting ice and sea level change 1 – sea ice: does sea level change when floating sea ice melts? Melting ice and sea level change 2 – ice caps Does sea level change when ice caps melt? Sea level in a plastic cup: eight ways to change the water level in a plastic cup – and global sea level How will rising sea level affect our coastlines? … and what can be done to adapt to rising sea levels?
d. The fragmentary terrestrial record of climate change contrasts with a near complete oceanic record: oxygen isotope evidence (18O/16O) from ocean sediments provides evidence of climate fluctuations through the Quaternary.	The oxygen isotope sweet simulation - Demonstrating how the oxygen isotope proxy records past Earth temperatures
e. Ice core evidence for atmospheric change.	Interpret Earth temperatures from simulated deep-sea and ice cores -Using sweets to simulate oxygen isotope ratios in cores How can the ice core evidence for climate change be explained? An educational opportunity for discussing evidence, hypotheses and possible responses

T3 Key Idea 3: Fossils provide evidence of environmental and climate changes in the Quaternary to which dating techniques can be applied	

a. Fossils provide evidence for climatic fluctuations in Britain during the Quaternary period. Analysis of pollen diagrams. Analysis of the vertebrate /invertebrate record. (e.g. woolly mammoths, beetles).	
b. Environmental change and climate instability over the past six million years may have been responsible for shaping human evolution and the ability to adapt to changing conditions. Evaluation of fossil evidence for hominin evolution (up to *Homo sapiens)* compared to the evidence for environmental and climatic change.	
c. A variety of techniques are available to date Quaternary events including: • Radiocarbon (14C) dating (organic material) • Incremental dating (varves, tree rings) • Isochronous marker beds (volcanic ash layers).	
Each method has particular applications and limitations.	

Option T4: GEOLOGICAL EVOLUTION OF BRITAIN	
Key Idea 1: The Neoproterozoic and Phanerozoic stratigraphy of the British area has been determined largely by the assembly of lithotectonic terranes during three orogenic events	*See earlier sections for activities involving fold and fault structures and mapwork*
a. Rocks from all the major subdivisions of geological time occur in Britain and surrounding shelf areas: Precambrian, Early and Late Palaeozoic, Mesozoic, Cenozoic. Study of geological maps at various scales including maps linking onshore and offshore areas. Use of maps and related data to investigate major geological processes operating in different parts of the British area from the Precambrian to the Quaternary.	
b. Information used to investigate the geological history of the British Isles also includes remote sensing techniques that provide an indirect way to investigate the subsurface geology. The principles associated with: • potential field measurements gravity (Bouguer anomaly) and magnetic surveys • borehole analysis; as exemplified by the Mochras Borehole • seismic reflection surveys; onshore and offshore.	Modelling remote sensing geophysics

Application of remote sensing and subsurface data collection to help interpret the Palaeozoic and Neoproterozoic geology of the British area.	
c. A number of orogenic events have affected the British area: location and large-scale geology. Ages, main structures and dominant trends of the Caledonian and Variscan orogenic belts; Alpine orogenic influences in Britain. Interpretation of geological maps to identify outcrop patterns associated with large-scale geological features of orogenic belts; fold shapes and descriptors, plunging folds; fault descriptors; regional structural trends as displayed by major folds and faults.	
d. Study of the geology (plutonic/volcanic and metamorphic rocks) of these orogenic belts aids the reconstruction of the plate tectonic regimes in which they developed. Collation and evaluation of geological evidence to interpret the Caledonian and Variscan orogenic belts and Palaeogene Igneous Province in plate tectonic terms.	
e. The Palaeogene Igneous Province of NW Britain provides evidence of the early history of the opening of the North Atlantic Ocean, with associated basaltic volcanicity. Interpretation of the geological characteristics of the Palaeogene Igneous Province in plate tectonic terms.	

T4 Key Idea 2: The evidence for the northward drift of the British area through the Neoproterozoic and Phanerozoic Knowledge and understanding Geological techniques and skills	
a. The palaeomagnetic field direction in some British rocks provides evidence of latitude at the time of magnetisation. The use of palaeomagnetic data to calculate palaeolatitudes for the British area, and interpretation of apparent polar wandering curves to determine palaeolatitude changes through time.	
b. Rocks in Britain show evidence of major climatic change through Phanerozoic time as a result of the northward drift of the British area, exemplified by: Devonian and Permo-Triassic – semiarid and desert terrestrial and hypersaline marine deposits. Carboniferous, Jurassic and Cretaceous - tropical, shallow marine and terrestrial (coal) deposits.	

T4 Key Idea 3: The northward drift of the British area as controlled by plate tectonic motions has resulted in the deposition of a wide range of sedimentary facies during the Neoproterozoic and Phanerozoic (from 1000Ma to 2.6Ma)	***See earlier sections for activities involving depositional environments etc***
NB: This key idea is intended to provide "snapshots" of the geological past to develop an appreciation of the global plate tectonic controls underlying regional geology and to increase understanding of changing plate environments within and beyond the British area. Detailed stratigraphical development is not required.	
a. Sedimentary rocks deposited in Britain are related to the interplay of global plate tectonics and associated climatic changes:	
1. *Neoproterozoic.* The break-up of the super-continent, Rodinia. Link to the cooling of the global climate around 700 Ma.	
2. *Early Palaeozoic*. Northern and southern parts of Britain in different continents separated by the Iapetus Ocean. Deep and shallow marine environments.	
3. *Mid Palaeozoic*. Caledonian Orogeny and fusion of Euramerica.	
4. *Late Palaeozoic*. Britain drifted north across the equator with possible destruction of a tract of oceanic lithosphere during the Variscan Orogeny.	
5. *Early Mesozoic*. Separation of Laurasia and Gondwana by the Tethys ocean in southern Europe. Rifting and subsidence in the North Sea area related to the opening of the Atlantic Ocean.	
6. *Late Mesozoic*. During the Cretaceous, continued opening of the Atlantic and continued subsidence of the North Sea area.	
7. Ce*nozoic*. Formation of the Alps with related tectonic uplift in the British area. Ongoing subsidence in North Sea area.	
Interpretation of maps, fossils, sedimentary rocks and structures to evaluate the evidence for changing depositional with particular reference to:	
1. an evaluation of the “Snowball Earth” hypothesis with evidence from Britain: diamictites of the Port Askaig formation; rapid evolution of primitive life in the Ediacaran fauna – Charnia.	
2. shallow seas: Cambrian and Silurian sandstones, shales and limestones with shallow water fossil assemblages including corals, brachiopods, trilobites; deep seas: Ordovician black graptolitic shales and turbidites.	
3. continental red beds: Devonian sandstones; breccias; conglomerates; mudstones.	
4. equatorial rain forest conditions: Carboniferous coal measures with sandstones, shale, freshwater bivalves and plant remains. Coal seams and seat-earths with rootlets.	
5. continental red beds and evaporites. Permo-Triassic - semi-arid and desert terrestrial; hypersaline marine deposits; Jurassic shallow marine shelf deposits.	

6. open marine Cretaceous chalk deposits recording a period of high global temperatures and sea levels.	
7. shallow and non-marine Paleogene deposits recording transgressive-regressive cycles.	

Option T5: GEOLOGY OF THE LITHOSPHERE	***See earlier sections, e.g. F4 for activities involving Earth's structure***
Key Idea 1: The Earth's heat loss leads to cooling and the development of a strong outer shell (lithosphere) underlain by a layer of lower strength (asthenosphere)	
a. The Earth loses heat through its surface, leading to the formation of a cold, rigid outer layer known as the lithosphere: surface heat flow and temperature variation with depth, rock strength related to temperature. Graphical comparison of continental and oceanic geotherms with the mantle solidus curve to explain lithosphere/asthenosphere distinction. Ray path modelling to show refraction of earthquake body waves through low velocity zone.	
b. The base of the lithosphere is defined as the 1300°C isotherm; lithospheric thickness differs between continents and oceans.	
c. Global seismology provides evidence for the distinction between lithosphere and asthenosphere: seismic low velocity zone in upper mantle. Ray path modelling to show refraction of earthquake body waves through low velocityzone. Interpretation of P- and S- wave velocity- depth curves and identification of low velocity zone.	
d. The crust is a surface layer of distinctive composition at the top of the lithosphere: seismological estimates of crustal thickness; Mohorovičić discontinuity (Moho). Simple interpretation of seismic refraction data to define crustal layering and reflection data to investigate the internal structure of the crust.	
e. The generation of magma in different geological settings results in a range of igneous bodies and products: oceanic ridge systems (including mid-ocean ridge basalts (MORBs)), large igneous provinces (LIPs), island arcs and cordilleran mountain belts. Interpretation of heat flow variation across an ocean basin.	Model a spreading ocean floor offset by transform faults Faults in a Mars™ Bar Pulling apart a Mars™ Bar to model a divergent plate margin

Evaluation of the evidence for the existence of mantle plumes.	

Key Idea 2: Oceanic lithosphere is formed at divergent plate boundaries and reabsorbed by subduction at convergent plate boundaries	
a. The ocean crust has a layered structure: seismic layers 1, 2 and 3. Geological interpretation of seismic layers 1, 2 and 3 (sediments, pillow lavas, sheeted dykes and gabbro) using evidence from ophiolites and ocean drilling.	
b. Ophiolites and ocean drilling provide evidence for the origin and composition of the oceanic crust and upper mantle. Investigation of an ophiolite complex.	
c. Ocean basin evolution can be traced from continental rifts through narrow seas to mature ocean basins: the J. Tuzo Wilson cycle. Analysis of the evidence for ocean growth and destruction as a cyclic event.	
d. Rates and directions of seafloor spreading may be calculated from the dating of oceanic crust and from the patterns of ocean magnetic anomalies caused by field reversals: use of radiometric dating and ocean drilling to date magnetic anomalies. Interpretation of ocean magnetic anomaly profiles and maps and ocean floor age distribution maps; calculation of rates of seafloor spreading from magnetic anomaly and mantle plume (hotspot) data – plumes as frames of reference for absolute plate movements.	

T5 Key Idea 3: A wide range of lithospheric processes contributes to the formation of continental crust	
a. Supercontinents have assembled and dispersed multiple times in the geologic past and takes place in cycles on a global scale: e.g. Rodinia, Pangea. Investigation of the concept of a supercontinent and the limitation in evidence beyond 200 Ma.	Continental jigsaw puzzle (ELI+) The pattern of continents/oceans versus the pattern of life on Earth
b. Being of relatively low density, continental lithosphere resists subduction and tends to avoid destruction during plate tectonic cycles, hence the Earth's oldest crustal rocks are found in continental areas. Investigation of the age distribution of rocks in continental areas using geological maps.	
c. Orogenic belts are sites of major lithospheric thickening. • continent- continent collision.	Isostasy 1 (ELI+) Isostasy 2 (ELI+)

- continent-island arc collision. - cordilleran mountain belts. - incorporation of oceanic lithosphere into orogenic belts; ophiolites and accretionary prisms - partial melting and granite. - magmatism; delamination. - isostatic uplift and gravitational collapse. Identification of large scale features of continental geology and interpretation of their origin and tectonic setting. Investigation of isostasy in continental and oceanic lithosphere.	Isostasy - “Hooray and up she rises!” View from above: living tectonism
d. Forces acting on the continental crust (plate boundary forces and gravitational spreading) give rise to tectonic stresses that cause brittle and ductile deformation on all scales in crustal rocks. Field interpretation of folds and faults in terms of applied stresses, and their relationship to the regional structural setting.	
e. Regional structures. - fold and thrust belts - nappe structures occur in compressive tectonic settings and may include large-scale recumbent folds together with shearing along low angle, thrust faults.	Margarine mountain-building
f. Major sedimentary basins are controlled by lithospheric extension (extensional basins) and lithospheric loading (foreland basins). Investigation of the origin and structural control of major sedimentary basins using maps and sections.	

SP1: Investigation of diagnostic properties of minerals: colour, crystal shape, cleavage, fracture, hardness, relative density, streak, lustre, reaction with cold dilute (0.5 mol dm^{-3}) hydrochloric acid.	
SP2: Measurement of the density of minerals.	
SP3: Application of classification systems using distinguishing characteristics to identify unknown minerals.	
SP4: Production of scaled annotated scientific drawings of rock samples from hand samples using a light microscope, or hand lens observation.	
SP5: Production of full rock description of macro and micro features from hand specimens and unfamiliar field exposures of sedimentary rocks in order to interpret component composition, colour and textures, to identify rock types and to deduce their environment of deposition.	

SP6: Construction of graphic logs using appropriate scale and symbol sets for unfamiliar geological sequences and exposures to record data relevant to an investigation.	
SP7: Use of photomicrographs to identify minerals and rock textures of sedimentary rocks in order to identify rock types and to deduce their environment of deposition.	
SP8: Production of full rock description of macro and micro features from hand specimens and/or unfamiliar field exposures of igneous rocks in order to interpret component composition, colour and textures, to identify rock type and to deduce their cooling history.	
SP9: Use of photomicrographs to identify minerals and rock textures of igneous rocks to identify rock type and to deduce their cooling history.	
SP10: Production of full rock description of macro and micro features from hand specimens and/or unfamiliar field exposures of metamorphic rocks in order to interpret component composition, colour and textures, to identify rock type and to deduce the temperature and pressure conditions of their formation.	
SP11: Use of photomicrographs to identify minerals and rock textures of metamorphic rocks to identify rock type and to deduce the temperature and pressure conditions of their formation.	
SP12: Location of geological features onto a base map.	
SP13: Identification of the location of geological features in the field using six figure grid references on maps.	
SP14: Production of scaled, annotated field sketches at unfamiliar field exposures to record data relevant to an investigation.	
SP15: Measurement of dip and strike elements: dip angle, dip and strike directions of planar surfaces, including valid sampling, relevant to an investigation.	Mapping "structures" on the playing field An exercise in measuring strike and dip
SP16: Application of classification systems using distinguishing characteristics to identify unknown fossils.	
SP17: Production of scaled, annotated scientific drawings of fossils, using a light microscope, or hand lens observation.	
SP18: Measurement of the densities of representative samples of Earth layers (e.g. granite, basalt).	
SP19: Investigation of the relationships between earthquake data (focal depth, magnitude and distance from plate boundaries) using data on Google Earth^{TM}.	
SP20: Investigation of contact metamorphism using the 'Metamorphic Aureole' simulation experiment.	

FIELDWORK –Earth Learning ideas

Fieldwork: ‘All powerful’ strategy
Fieldwork: Applying ‘the present is the key to the past’
Fieldwork: Environmental evaluation
Fieldwork: Interactive re-creation
Fieldwork: Now and then – spotting the difference
Fieldwork: Questions for any rock face - Planning for fieldwork
Fieldwork: Questions for any rock face 1: weathering
Fieldwork: Questions for any rock face 2: erosion
Fieldwork: Questions for any rock face 3: soil
Fieldwork: Questions for any rock face 4: rock group (sedimentary or igneous)

Fieldwork: Questions for any rock face 5: sedimentary grains
Fieldwork: Questions for any rock face 6: fossils
Fieldwork: Questions for any rock face 7: tilted or folded rocks
Fieldwork: Questions for any rock face 8: faults
Fieldwork: Questions for any rock face 9: metamorphic rock
Fieldwork: Questions for any rock face 10: sequencing
Fieldwork: Questions for any rock face 11: tectonic plates
Fieldwork: Questions for any rock face 12: potential of the quarry or cutting
Fieldwork: Questions for any rock face 13: quarry economics
Fieldwork: Questions for any rock face 14: recording
Fieldwork: The view from the site
Fieldwork: The ‘What makes a good educational experience?’ approach to planning fieldwork
Fieldwork: The ‘What could hurt you here?’ approach to field safety -teaching how to keep safe during fieldwork and other outdoor activities
Fieldwork: Mystery Isle: Plan a geological survey of a fascinating island
Fieldwork: Some classic Scottish geology revealed: How good are you at establishing a geological history from photographs?
Fieldwork: Every rock tells a story: Reading the rock history from an exceptional specimen of slate

Appendix

“Net-zero” carbon emissions

In preparation for the COP26 U.N. Climate Change Conference in November 2021, Earthlearningidea prepared a series of 28 activities, covering mitigation and adaptation measures which might be implemented in order to achieve zero carbon emissions by 2050. They are being revised as necessary and published on a fortnightly basis as usual, but teachers may wish to use the 28 drafts before then, and they are all shown on the webpage https://www.earthlearningidea.com/home/Net_zero.html
Some of the activities impinge on a number of existing topics in the Specification, but they will be listed fully here, rather than in the table above:

3.5.2021	How will the ‘net-zero’ target affect your local area? Assessing the local impact of the government’s ‘net-zero’ targets for carbon emissions
17.5.2021	Capturing carbon? Can we capture and store carbon from burning fuel, cement- and steel-making? Should we?
14.6.2021	Blue Hydrogen – the fuel of the future? Could “blue” hydrogen be produced and used here?
28.6.2021	Harnessing the power of the Sun. Could solar farms be used in your area?
26.7.2021	Tidal energy Can the tides be harnessed to produce green energy?
9.8.2021	How will rising sea level affect our coastlines? … and what can be done to adapt to rising sea levels?
6.9.2021	Heat from the Earth: Investigating ground source heat pumps
20.9.2021	Green hydrogen used to even out renewable energy supplies? Could ‘green hydrogen’ be the solution to the efficient use of renewable energy?
18.10.2021	Energy from burning waste: Where does all my non-recyclable waste go?
1.11.2021	Hydrogen of many colours: The situation regarding hydrogen in the UK, October 2021
15.11.2021	Energy from buried waste: Landfill gas
29.11.2021	Small-scale hydroelectric power schemes: Investigating opportunities for micro-hydro
13.12.2021	A new use for old coal mines A potential source of energy from beneath our feet
27.12.2021	Let's plant some trees: Investigating the importance of trees to our planet
2.2.2022	Nuclear waste disposal Investigating geological disposal facilities (GDFs)
21.2.2022	Deep geothermal power from ‘hot dry rocks’: an option in your area? A discussion of potential for extracting ‘hot dry rocks’ geothermal energy
21.3.2022	Harnessing the power of waves: investigating the development of wave power
4.4.2022	Storing gas underground: What can we store? How can we do it? How will it help?
2.5.2022	The future for global agriculture: The adaptation of agriculture to climate change

16.5.2022 Nuclear batteries - the future? Investigating advances in battery technology
13.6.2022 Farming the wind – through onshore and offshore windfarms: A discussion on the local and national potential of developing wind energy sources
11.7.2022 Liquid biofuels - keeping our wheels turning into the future: Investigating fuels produced from biomass
8.8.2022 Inland flooding: a Sheffield case study. How should we respond to the increased risk of inland flooding as temperatures rise?
5.9.2022 Matching supply and demand using stored water: Pumped storage hydroelectric schemes – just-in-time power
19.9.2022 How do I choose the best insulation? Investigating enhanced insulation for buildings
17.10.2022 Electric vehicles - the way to go? Investigating the advantages and disadvantage of EVs
31.10.2022 Speeding up nature to trap carbon dioxide: The potential role of enhanced weathering and carbonation in mitigating climate change
28.11.2022 Nuclear power - harnessing the energy of the atom: Investigating the use of nuclear power now and in the future
12.12.2022 Landslide danger – and climate change: Case studies of how landslides work and the likely effects of climate change