GCE AS

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WJEC Eduqas GCE AS in

GEOLOGY

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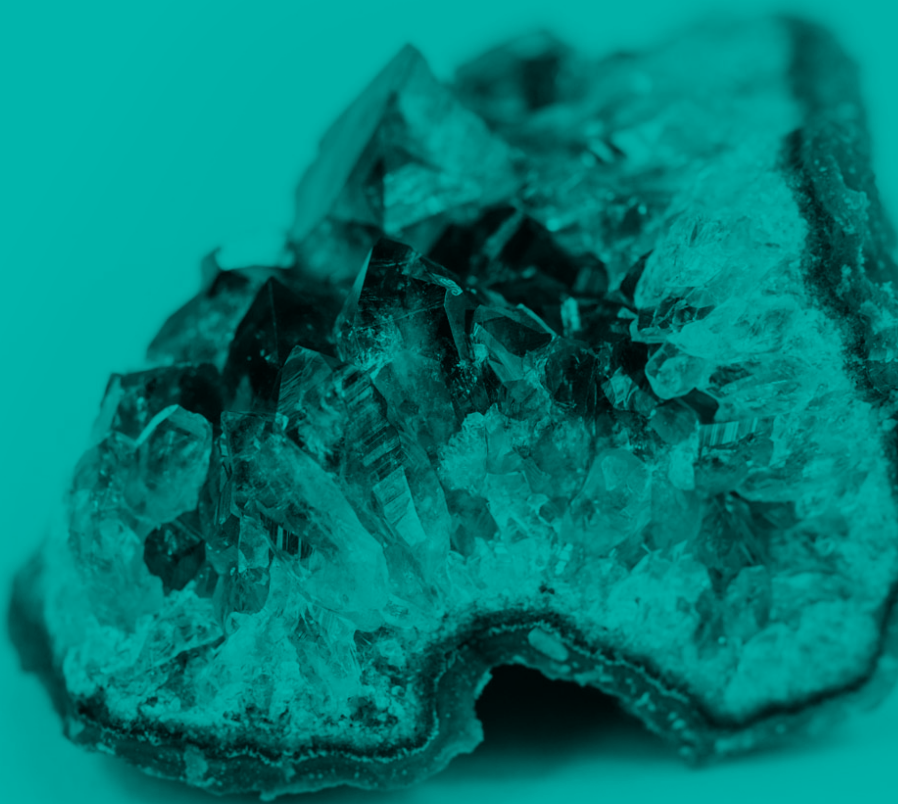
GUIDANCE FOR TEACHING

Teaching from 2017
For award from 2018



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Introduction

The **WJEC Eduqas AS Geology** qualification, accredited by Ofqual for first teaching from September 2017, is available to:

- All schools and colleges in England
- Schools and colleges in independent regions such as Northern Ireland, Isle of Man and the Channel Islands

The A level will be awarded for the first time in Summer 2018, using grades A- E.

The qualification provides a broad, coherent, satisfying and worthwhile course of study. It encourages learners to develop confidence in, and a positive attitude towards, geology and to recognise its importance in their own lives and to society.

The specification is intended to promote a variety of styles of teaching and learning so that the course is enjoyable for all participants..

Practical work is an intrinsic part of geology, and is highly valued by higher education. It is imperative that practical skills are developed throughout this course and that an investigatory approach is promoted.

Additional ways that WJEC Eduqas can offer support:

- Specimen assessment materials
- Face-to-face CPD events
- Question paper database
- Examiners' reports on each question paper
- Free access to past question papers and mark schemes via the secure website
- Direct access to the subject officer
- Free online resources
- Exam Results Analysis
- Online Examination Review

If you have any queries please do not hesitate to contact:

David Evans
Subject Officer – Geology
david.evans@eduqas.co.uk

Aims of the Guidance for Teaching

The principal aim of the Guidance for Teaching is to support teachers in the delivery of the new **WJEC Eduqas AS Geology** specification and to offer guidance on the requirements of the qualification and the assessment process.

The guidance is **not intended as a comprehensive reference** but as a support for professional teachers to develop stimulating and exciting courses tailored to the needs and skills of their own learners in particular institutions.

The guidance offers assistance to teachers with regard to the depth of coverage required as well as links to useful digital resources (both our own, freely available, digital materials and some from external resources) to provide ideas for engaging lessons.

Possible Delivery Model

	AS Geology	A level Geology
Year 12 Term 1	Topic 1 Elements minerals and rocks Topic 2 Surface and internal processes of the rock cycle	F1 Elements minerals and rocks F2 Surface and internal processes of the rock cycle
Year 12 Term 2	Topic 3 Time and change Topic 4 Earth structure and global tectonics	F3 Time and change F4 Earth structure and global tectonics
Year 12 Term 3	Revision AS exams	(Revision) (Internal Examinations/AS exams) G1 Rock forming processes G2 Rock deformation
Year 13 Term 1		G3 Past life and past climates G4 Earth materials and natural resources T1 Geohazards KI 1 and 2
Year 13 Term 2		T1 Geohazards KI 3 T2 Geological map applications Option Key Idea 1
Year 13 Term 3		Option Key Ideas 2 & 3 Revision

Note: The WJEC Eduqas A level specification is designed to be co-teachable with the specification for the WJEC Eduqas AS in Geology. The content within the A level specification Fundamentals of Geology section (F1-F4) forms the entire content required in the AS specification (Topics 1-4), with the exception of:

- some additional exemplification of mathematical skills required at A level but not at AS
- a practical activity required at AS but not A level.

Assessment Objectives

	Objective
AO1	Demonstrate knowledge and understanding of geological ideas, skills and techniques. 1a: Demonstrate knowledge of geological ideas 1b: Demonstrate knowledge of geological skills and techniques 1c: Demonstrate understanding of geological ideas 1d: Demonstrate understanding of geological skills and techniques
AO2	Apply knowledge and understanding of geological ideas, skills and techniques. 1a: Apply knowledge and understanding of geological ideas 1b: Apply knowledge and understanding of geological skills and techniques
AO3	Analyse, interpret and evaluate geological ideas, information and evidence to make judgements, draw conclusions, and develop and refine practical design and procedures. 1a: Analyse geological ideas, information and evidence 1b: Interpret geological ideas, information and evidence 1c: Evaluate geological ideas, information and evidence 1d: Make judgements 1e: Draw conclusions 1f: Develop and refine practical design and procedures

The following questions in the sample assessment materials exemplify the WJEC interpretation of each of the assessment objectives:

AO1 1a: Demonstrate knowledge of geological ideas
Component 2 Q2 a (i) asks learners to define the half-life of a radioactive isotope. Since the question requires learners to demonstrate their knowledge of a geological idea it is classed as AO1 element 1a.

AO1 1b: Demonstrate knowledge of geological skills and techniques
e.g Component 2 Q2 a (ii) requires learners to apply their knowledge of radiometric dating to the completion of a table concerning parent and daughter isotopes. This involves applying geological knowledge to practical contexts, a practical skill contained within Appendix 1a of the DfE GCE AS and A level Subject Content for Geology document and hence is assigned to AO1 element 1b.

AO1 1c: Demonstrate understanding of geological ideas
e.g Component 2 Q3 b requires learners to demonstrate understanding of how features of graptolites impact upon three of their characteristics. This is therefore demonstration of understanding of geological ideas and is assigned to AO1 element 1c.

AO1 1d: Demonstrate understanding of geological skills and techniques
e.g. Component 2 Q1 d requires learners to construct an annotated drawing of the appearance of a described sandstone if viewed through a hand-lens. Producing such drawings is a practical skill contained within Appendix 1c of the DfE GCE AS and A level Subject Content for Geology document, hence this item is assigned to AO1 element 1d.

AO2 1a: Apply knowledge and understanding of geological ideas
e.g. Component 1 Q1 b asks learners to provide evidence from a map and a hand specimen to support the statement that Rock Unit A is a pluton. This requires learners to apply their knowledge of geological ideas to a map and hand specimen and consequently is classed as AO2 element 1a.

AO2 1b: Apply knowledge and understanding of geological skills and techniques
e.g. Component 1 Q4 c asks learners to draw onto a geological base map, from described information. This involves learners using geochronological principles to solve a problem, both of which are practical skills and techniques as described in Appendix 1d of the DfE GCE AS and A level Subject Content for Geology document. Since this involves the application of geological skills and techniques it is classed as AO2 element 1b.

AO3 1a: Analyse geological ideas, information and evidence
e.g. Component 2 Q2 b (iv) requires learners to come to a conclusion (AO3 element1e) regarding the relative age of two features after having analysed the evidence on a map (AO3 element 1a). For this reason two of the three marks available are classed as AO3 element 1a and the remainder AO3 element 1e.

AO3 1b: Interpret geological ideas, information and evidence
e.g. Component 2 Q3 c requires learners to make a judgement in relation to evidence in a diagram and a passage concerning the relative value of two graptolites as zone fossils. Consequently two of the marks are awarded within AO3 element 1b for interpreting geological information, ideas and evidence. The remaining mark is awarded within AO3 element 1d because it requires learners to make a judgement.

e.g. Component 1 Q5 requires learners to transfer information from a geological map in order to construct a geological cross-section. Where features outcrop on the surface the transfer of information is a straightforward practical technique and these marks are assigned to AO2 1b. Where features do not outcrop at the surface they need to be interpreted and consequently these marks are assigned to AO3 element 1b.

AO3 1c: Evaluate geological ideas, information and evidence
e.g. Component 1 Q3 c requires learners to evaluate a series of statements and to explain the evidence for the evaluation from a map and a photograph. The requirement to evaluate leads this item to be classed as AO3 element 1c.

AO3 1d: Make judgements
e.g. Component 2 Q3 c requires learners to make a judgement in relation to evidence in a diagram and a passage concerning the relative value of two graptolites as zone fossils. Consequently two of the marks are awarded within AO3 element 1b for interpreting geological information, ideas and evidence. The remaining mark is awarded within AO3 element 1d because it requires learners to make a judgement.

AO3 1e: Draw conclusions
e.g. Component 2 Q2 b (iv) requires learners to come to a conclusion (AO3 element 1e) regarding the relative age of two features after having analysed the evidence on a map (AO3 element 1a). For this reason two of the three marks available are classed as AO3 element 1a and the remainder AO3 element 1e.

AO3 1f: Develop and refine practical design and procedures

e.g. Component 1 Q4 d (i) asks learners to describe a test that could be used to identify a mineral. It requires learners to design a relevant test for a given mineral. This is therefore assigned to AO3 element 1f.

Topic 1: ELEMENTS, MINERALS AND ROCKS		
Key Idea 1: **The Earth is composed of rocks which have distinctive mineralogies and textures**		
Knowledge and understanding	**Geological techniques and skills**	**Comments**
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).		Candidates should be aware of the four-fold classification and its delineation and be able to name at least one element from each group. lithophile: elements that combine well with oxygen and are concentrated in the crust; siderophile: 'iron loving' elements typical of the core; chalcophile: 'ore loving' elements which combine well with sulfur near the Earth's surface; atmophile: volatile elements within liquids and gases on or above the Earth's surface.
b. The bulk composition of the Earth is comparable with that of undifferentiated meteorites (chondrites).		Candidates should know that evidence for the internal composition of the Earth partly comes from chondrite meteorites.
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.	Candidates should know that 99% of the Earth's crust (by weight) is made up of just 8 elements and their relative order of abundance.

Knowledge and understanding	Geological techniques and skills	Comments
d. Silicates are the commonest rock-forming minerals and are built from silicon-oxygen tetrahedral (single, chain, sheet and framework silicates).	Simple analysis of silicate mineral structures from models and diagrams.	Candidates should know the chemical structure of silicates as it relates to the physical properties of minerals (e.g. crystal shape, hardness and cleavage) rather than details of the chemical variations between minerals. As exemplified by olivine (single tetrahedra), augite/pyroxene (single chain),hornblende/amphibole (double chain), micas (sheet) and quartz/feldspar (framework).
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.	P1: 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. P2: 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.	Candidates should be able to investigate the physical/chemical properties of minerals (including unfamiliar minerals) in the laboratory and field. Candidates should be able to measure the density of minerals using an appropriate technique and evaluate the accuracy of such calculations. Candidates will be required to use a mineral data sheet of diagnostic mineral properties in their identification of the stated minerals.

Knowledge and understanding	Geological techniques and skills	Comments
	P3: Application of classification systems using distinguishing characteristics to identify unknown minerals.	Candidates should be able to use flow charts to classify minerals (including unfamiliar minerals) from their observed physical/chemical properties.
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.	Observation and investigation of hand specimens of a variety of rocks (including sampling in the field) in order to: • identify and interpret component composition • interpret colour and textures (crystalline/clastic; crystal or grain size/shape; sorting; foliation; mineral alignment/bedding/cryst-alline banding) and hence • deduce the mode of origin of the rock as igneous, metamorphic or sedimentary. P4: Production of scaled annotated scientific drawings of rock samples from hand samples using a light microscope, or hand lens observation. • *Use and manipulation of the magnification formula* $\textit{magnification} = \dfrac{\textit{size of image}}{\textit{size of real object}}$	Candidates should be able to determine the origin of igneous, sedimentary and metamorphic rocks from their differing textures and mineralogies (including unfamiliar rocks) in the laboratory and field. Scientific drawings to include samples in the laboratory and the field using appropriate scales.

Topic 2: 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**		
Knowledge and understanding	**Geological techniques and skills**	**Comments**
a. External energy: solar heating of the Earth's surface drives the water cycle and influences weathering and erosional processes.		
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.		Candidates should know that the products of weathering are rock fragments, unreactive grains (e.g. quartz), clay minerals (e.g. kaolinite) and ions in solution. Candidates need only know the processes outlined.

Knowledge and understanding	Geological techniques and skills	Comments
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.	*Recognition and use of appropriate units in calculations.* *Construction and interpretation of frequency tables and diagrams, bar charts and histograms.* *Finding of arithmetic means.* *Understanding of the principles of sampling as applied to scientific data.* *Understanding of the measures of dispersion, including standard deviation and interquartile range.*	The surface processes part of the rock cycle facilitates, (though not exclusively) training in, and assessment of, some mathematical skills. *For exemplification of mathematical skills see* ***Mathematical Guidance for AS Geology***.
d. Different sedimentary environments may be identified by diagnostic sedimentary structures, rock textures, mineralogy and fossil content.	Description of sedimentary rocks in hand specimens, 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.	

Knowledge and understanding	Geological techniques and skills	Comments
e. A study of fluvial, marine, and aeolian sediments demonstrates these differences.	Investigation of textures of sediments from different depositional environments. P5: 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. P6: Construction of graphic logs using appropriate scale and symbol sets for unfamiliar geological sequences and exposures to record data relevant to an investigation. P7: 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. 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).	Candidates should be aware of the link between process and product in their studies of the stated sedimentary environments: • fluvial (rivers, deltas alluvial fans and playa lakes) • aeolian (wind dominated e.g. desert dunes) • marine (shallow water – lagoon/reef/beach systems) • marine (deep water – submarine fan turbidites) Candidates should be able to explain the formation of the stated sedimentary structures.

Knowledge and understanding	Geological techniques and skills	Comments
	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. Investigation of contrasts between fluvial, marine and aeolian sediments. *Construction and interpretation of frequency tables and diagrams, bar charts and histograms.* *Understanding of the terms mean, median and mode.* *Plotting of two variables from experimental or other linear data.*	Candidates need only have knowledge of the sedimentary rocks indicated. Candidates should be able to identify the stated sedimentary rocks in hand specimen and the field. It is understood that it might not be possible to investigate the full range of rocks in the field or that this list is exclusive. *For exemplification of mathematical skills see* ***Mathematical Guidance for AS Geology***. *The mathematical skills identified are not exclusive to this section of the specification.*
f. Sedimentary rocks may result from the accumulation of organic material (limestone, coal) or by precipitation of solid material from solution (evaporites).	Analysis of biogenic components in sedimentary rocks.	Candidates should be able to describe the order of precipitation of evaporate minerals from seawater in terms of their relative solubilities – low → high. (calcite/dolomite → gypsum/anhydrite → halite → potassium/magnesium salts).

Knowledge and understanding	Geological techniques and skills	Comments
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 • post-depositional factors as sediments are formed into sedimentary rocks: diagenesis and lithification (compaction, recrystallisation, cementation, pressure solution).	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. *Understanding that* $y = mx + c$ *represents a linear relationship.*	Candidates should be aware of the range of texture in descriptive terms (as used on a grain size comparator): • angularity – very angular to well rounded • sphericity – high to low sphericity • size – reference to the Wentworth scale • sorting – very well to poorly sorted *For exemplification of mathematical skills see **Mathematical Guidance for AS Geology**.* *The mathematical skills identified are not exclusive to this section of the specification.*

Topic 2: **SURFACE AND INTERNAL PROCESSES OF THE ROCK CYCLE**

Key Idea 2: **The formation and alteration of igneous and metamorphic rocks result from the Earth's internal energy**

Knowledge and understanding	Geological techniques and skills	Comments
a. Internal energy: The Earth's internal geological processes result from the transfer of energy derived from radiogenic and primordial heat sources. 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). *Calculation of the rate of change from a graph showing a linear relationship.*	Candidates should be able to interpret pressure (depth) temperature graphs and use them to calculate geothermal gradients. *For exemplification of mathematical skills see **Mathematical Guidance for AS Geology**.* *The mathematical skills identified are not exclusive to this section of the specification.*
b. Igneous rocks are the products of cooling of magma in bodies of various sizes and shapes and pyroclastic events.	The recognition of plutons, dykes, sills, lava flows and pyroclastic deposits by interpretation of maps, sections and photographs. 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.	

Knowledge and understanding	Geological techniques and skills	Comments
	P8: 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. 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. P9: Use of photomicrographs to identify minerals and rock textures of igneous rocks to identify rock type and to deduce their cooling history. *Use of ratios, fractions and percentages.* *Construction and interpretation of frequency tables and diagrams, bar charts and histograms.*	Candidates need only have knowledge of the igneous rocks indicated. Candidates should be able to identify the stated igneous rocks in hand specimen and the field. It is understood that it might not be possible to investigate the full range of rocks in the field or that this list is exclusive. *For exemplification of mathematical skills see* ***Mathematical Guidance for AS Geology***. *The mathematical skills identified are not exclusive to this section of the specification.*

Knowledge and understanding	Geological techniques and skills	Comments
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.	
d. Volcanic hazards result from: • blast/explosion • ash fall, pyroclastic flows (nuées ardentes) and gases • 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.	Candidates are expected to have studied specific examples of the stated hazards and monitoring techniques but will not be required to recall details of these examples in an assessment.

Knowledge and understanding	Geological techniques and skills	Comments
e. The nature of the volcanic hazard is linked to the composition, viscosity and gas content of the magma.		Candidates are expected to have studied the hazards associated with explosive and effusive activity and their links to silica and gas content that affects viscosity.
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.	Candidates should be aware of the concept of metamorphic grade.
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.	*Understanding that $y = mx + c$ represents a linear relationship*. P10: 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. P11: 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. 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.	*For exemplification of mathematical skills see* ***Mathematical Guidance for AS Geology***. *The mathematical skills identified are not exclusive to this section of the specification.* Candidates should be aware of the metamorphic changes in chemically varied clay-rich rocks (e.g. shale) compared to those dominated by quartz and calcite (sandstones and limestone). Candidates need only have knowledge of the metamorphic rocks indicated. Candidates should be able to identify the stated metamorphic rocks in hand specimen and the field. It is understood that it might not be possible to investigate the full range of rocks in the field or that this list is exclusive.

Topic 2: SURFACE AND INTERNAL PROCESSES OF THE ROCK CYCLE		
Key Idea 3: **Deformation results when rocks undergo permanent strain in response to applied tectonic stresses and can be interpreted using geological maps**		
Knowledge and understanding	**Geological techniques and skills**	**Comments**
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.		Candidates should be able to draw and interpret stress-strain curves.
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). Recognition and interpretation of structural features through study of photographs, diagrams, sections, geological maps and in the field. P12: Location of geological features onto a base map. P13: Identification of the location of geological features in the field using six figure grid references on maps. P14: Production of scaled, annotated field sketches at unfamiliar field exposures to record data relevant to an investigation.	

Knowledge and understanding	Geological techniques and skills	Comments
	P15: Measurement of dip and strike elements: dip angle, dip and strike directions of planar surfaces, including valid sampling, relevant to an investigation.	*Candidates should be aware of random, systematic and stratified sampling techniques relevant to an investigation. The sampling skills identified are not exclusive to this section of the specification.*
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.	Candidates should be aware that fold symmetry is a function of the length of the fold limbs rather than the dip of opposing limbs. Symmetric folds have limbs of equal length; asymmetric folds have limbs of different lengths.
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).	Candidates are not required to have knowledge of other fault elements.
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.	

Knowledge and understanding	Geological techniques and skills	Comments
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. Ordering the geological sequence of events in an area from the study of a simplified geological map and/or section.	

Topic 3: **TIME AND CHANGE**

Key Idea 1: **Study of present day processes and organisms enables understanding of changes in the geological past**

Knowledge and understanding	Geological techniques and skills	Comments
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.	Candidates should be able to apply the Principle of Uniformitarianism to evidence of rock cycle processes through Deep Time. A simple understanding of the contributions made by James Hutton (unconformity, Deep Time) and William Smith (principle of faunal succession, first geological map).
b. The study of modern environments enables an interpretation of the sedimentary rock record within the rock cycle model.		
c. The basic unit of sedimentary geology is the *facies* which reflects the depositional environment: lithofacies, biofacies.		Candidates should be aware that facies relates to the sum total of all the characteristics of a rock (composition, texture, fossil content) of a given age that change laterally. Lithofacies: a mappable unit based on petrological characters (e.g. texture and mineralogy) Biofacies: a mappable unit based on fossil content.

Knowledge and understanding	Geological techniques and skills	Comments
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). P16: Application of classification systems using distinguishing characteristics to identify unknown fossils. P17: Production of scaled, annotated scientific drawings of fossils, using a light microscope, or hand lens observation.	Candidates are only required to have knowledge of those morphological features stated that are used to identify the group.
e. Fossil morphology is used to interpret function/mode of life: • bivalves (burrowers/non burrowers) • trilobites (benthonic/pelagic).		

Knowledge and understanding	Geological techniques and skills	Comments
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.		
g. Fossil 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.	Candidates should be able to determine transport history based on the degree of fragmentation, sorting or alignment of specimens within a fossil assemblage.
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)		Candidates should be aware of the importance and limitations of a *Lagerstätte* in providing exceptional preservation e.g. Ediacaran (Precambrian), Burgess Shale (Cambrian), Wenlock Series (Silurian), Solnhofen (Jurassic).

Topic 3: TIME AND CHANGE

Key Idea 2: Geological events can be placed in relative and absolute time scales

Knowledge and understanding	Geological techniques and skills	Comments
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. P18: The application of one or more criteria of relative age (evolutionary change in fossils, superposition of strata, unconformities, cross-cutting relationships, included fragments, 'way-up criteria') in the field to place geological events in relative time sequences.	
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.	Candidates will need to know that differences between the K – Ar and Sm – Nd methods and understand the principle of using the gradient of an isochron to establish relative age in the latter. Candidates will not be expected to plot isochrons or calculate age from isochrons but simply interpret relative age.
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).	Candidates are expected to be able to provide a relative date to a formation based on graptolite or cephalopod assemblages within the appropriate time frame (Early Palaeozoic and Mesozoic).

Knowledge and understanding	Geological techniques and skills	Comments
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.	Interpretation of the ages of geological events using the geological column.	Candidates need to be aware of the classification and relative order of the geological column (based on the International Chronostratigraphic chart) – eons, eras, periods. Candidates should be aware that the Precambrian predates the Phanerozoic era, but knowledge of subdivisions of the Precambrian is not required.
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.		

Topic 4: EARTH STRUCTURE AND GLOBAL TECTONICS		
Key Idea 1: **The Earth has a concentrically zoned structure and composition**		
Knowledge and understanding	**Geological techniques and skills**	**Comments**
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. *Translation of information between graphical, numerical and algebraic forms.* P19: Measurement of the densities of representative samples of Earth layers (e.g. granite, basalt). Simple analysis of geomagnetic evidence for core composition and processes.	Candidates should be able to use evidence to interpret the state, depth and probable composition of the Earth's layers. *For exemplification of mathematical skills see* ***Mathematical Guidance for AS Geology***. *The mathematical skills identified are not exclusive to this section of the specification.*
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.	Interpretation of geophysical data on crustal structure (seismic, gravity, magnetic) from continental and oceanic areas. Analysis of ocean drilling data to re-interpret the Mohorovičić discontinuity (Moho) at the base of the crust (e.g. Joides Resolution 360).	Candidates should be given the opportunity to evaluate and validate the new knowledge obtained from current ongoing scientific research. • the significance of serpentinite at the Moho discontinuity https://www.cardiff.ac.uk/earth-ocean-sciences/about-us/supporting-education http://www.bbc.co.uk/news/science-environment-34967750 http://www.nature.com/news/quest-to-drill-into-earth-s-mantle-restarts-1.18921

Topic 4: EARTH STRUCTURE AND GLOBAL TECTONICS		
Key Idea 2: **The Earth's internal heat is the underlying cause of lithospheric plate motions that control global geological processes**		
Knowledge and understanding	**Geological techniques and skills**	**Comments**
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).	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).	Candidates should be aware of the importance of the plate tectonic model in providing an underlying framework to understand how the Earth works.
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.	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). P20: Investigation of the relationships between earthquake data (focal depth, magnitude and distance from plate boundaries) using data on Google Earth™.	Teachers may find the following resource useful in the delivery of Topic 4: https://www.geolsoc.org.uk/Plate-Tectonics

Knowledge and understanding	Geological techniques and skills	Comments
	Use of a scatter diagram to identify a correlation between two variables.	
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).	Candidates should be aware that currently the possible mechanisms for plate movement are much disputed.
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.		
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.		Candidates should be aware of remanent magnetic inclination in determining changes in continental latitude through geological time. Knowledge of Polar Wandering Curves is not required.

Knowledge and understanding	Geological techniques and skills	Comments
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.		

Useful additional resources

British Geological Survey https://www.bgs.ac.uk/

Earth Learning Ideas http://www.earthlearningidea.com/

Earth Science Teachers Association http://www.esta-uk.net/

United States Geological Survey https://www.usgs.gov/

Title: P1 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 in order to identify minerals

Specification reference: 1.1e

Aim: To use physical and chemical testing to identify minerals.

Apparatus:

Mineral testing equipment:
Streak plate/unglazed tile to test the colour of powdered minerals.

Dilute hydrochloric acid ("bench strength" 0.5 mol dm^{-3}) in a dropper bottle to test if a mineral is a carbonate.

Copper coin (pre 1992 coins are 97% copper, post 1992 they are copper plated steel), hardness ~3.5 on Mohs' scale.

Steel pin/needle (dissecting pin from Biology department or steel nail), hardness ~5.5 on Mohs' scale.

Learners to also use own fingernail, hardness ~2.5 on Mohs' scale.

Method:
Carry out the appropriate tests and record results.
Complete a table (similar to below) to logically record the results of observations.

Description and identification of mineral specimen X		
Colour		
Crystal shape		
Cleavage		
Fracture		
Hardness	mineral is scratched by	mineral is softer than
	mineral is not scratched by	mineral is harder than
	hardness of mineral is between and on Mohs hardness scale	
Density		
Streak		
Lustre		
Reaction with cold dilute HCl		
Conclusion: identification of mineral X		

Analysis:
1. Identify the mineral by appraising the results of the tests.
2. Compare the mineral identification reached with published results eg. Eduqas mineral data sheet or other sources.

Description and identification of mineral specimen X		
Colour	grey	
Crystal shape	some crystals show a definite cubic shape	
Cleavage	mineral cleaves along planes parallel to the edges of its cubic crystals	
Fracture	none, mineral has cleavage	
Hardness	mineral is scratched by copper coin	mineral is softer than
	mineral is not scratched by fingernail	mineral is harder than
	hardness of mineral is between ~2.5 and ~3.5 on Mohs hardness scale	
Density	no accurate measurement made, but specimen seemed heavy and dense when hefted	
Streak	light grey	
Lustre	metallic	
Reaction with cold dilute HCl	teacher advised me not to carry out this test	
Conclusion: identification of mineral X GALENA		

Teacher/Technician notes

Appropriate tests listed in the specification at 1.1e:

Colour: to be observed in natural light.

Crystal shape: common appearance of the mineral to be observed and use descriptive terms, learners might see individual well shaped crystals (form) or the shape of a mass of crystals when individual crystals cannot be seen when it is massive (habit). Commonly used terms to describe shape include rhombic, cubic, fibrous, kidney shaped.

Cleavage: to be observed and described in terms of number of cleavage planes and if multiple planes to look at how they intersect (e.g. one perfect, two planes at 90° or at 120°).

Fracture: to be observed and use descriptive terms, (e.g. conchoidal, uneven).

Hardness: tested by scratching the specimen with fingernail/copper coin/steel pin, observations can be checked using a hand lens. To be described in relative terms (harder than/softer than and link to figures, e.g. if a mineral is not scratched by a fingernail, but is scratched by a copper coin then it will have a hardness of ~2.5 - ~3.5).
If a mineral cannot be scratched by steel it has a hardness > 5.5.

Density: (**Hefting**) With practice learners may be able to judge which minerals feel heavy or light for their size when they pick up the specimen in their hand. Care must be taken to allow for the size of the specimen. It would be good to have similar sized specimens of quartz, barites, galena etc to compare.
Density: (**Calculation**) See P2.

Streak: the colour of a mineral's powder, to be obtained by rubbing a mineral specimen on an unglazed white porcelain tile/streak plate. To be described using the colour of the powdered mineral (e.g. white, black, greenish black, lead grey, cherry red), or a negative result if the mineral is harder than the tile and scratches it (e.g. scratches streak plate).

Lustre: the way the mineral reflects light, to be observed and recorded using descriptive terms (e.g. vitreous, pearly, silky, resinous, metallic, dull).

Reaction with cold dilute (0.5 mol dm^{-3}) hydrochloric acid: this is to test the mineral for carbonates. Observations to be described in terms of positive reactions (effervesces/fizzes) to identify carbonates, or no reaction to identify non-carbonate.

Minerals not listed on the specification (specified on the mineral data sheet) could also be tested and results observed. The photograph shows the positive reaction to application of cold dilute (0.5 mol dm^{-3}) hydrochloric acid and identification as a carbonate.

Health and Safety

1. If acid has been applied, then the specimen should be washed afterwards to remove any remaining acid.
2. Sulphide minerals should not be tested with acid.
3. Learners should wash their hands after handing mineral specimens.

Rock forming minerals listed (as specified on the mineral data sheet) in specification section 1.1e:
quartz, calcite, feldspars (orthoclase, plagioclase), augite, hornblende, olivine, micas (biotite, muscovite), haematite, galena, pyrite, chalcopyrite, fluorite, barite, halite, gypsum, garnet, chiastolite/andalusite.

Title: P2 Measurement of the density of minerals

Specification reference 1.1e

Density can be investigated using the formula $\text{Density} = \frac{\text{Mass}}{\text{Volume}}$

Aim: To determine the density of minerals using density formula.

Apparatus:
Samples of individual minerals (individual crystals or masses of crystals of one mineral)
Electronic balance
Water
Graduated (Measuring) cylinder

Method:
1. Select a mineral sample (individual crystal or mass of crystals of all the same mineral).
2. Determine the mass of the sample using an electronic balance. Record the result.
3. To determine volume there are 3 possibilities:

A. Immerse the specimen in the water in the graduated cylinder. Measure how much the water rises (in ml). Record the result. Convert to cm^3. ($1ml=1cm^3$); Record the result.

B. Place a beaker of water on a balance, zeroing the reading scale. Suspend the specimen on a thin thread and record the balance reading (it is important to suspend the specimen in water and not to let it rest on the bottom of the beaker or touch the sides). This measurement (recorded in grams) can be converted to a volume for the density calculation ($1g = 1cm^3$).

C. Where the mineral specimen has a regular shape (e.g. cuboid/rhombic crystals) the volume may be determined directly by measuring the length, width and height of the mineral.

Analysis:
1. Calculate the density of the sample using the formula $\text{Density} = \frac{\text{Mass}}{\text{Volume}}$

2. Compare the density value you have calculated with published results e.g. Eduqas mineral data sheet or other sources.

Teacher/Technician notes:
This method cannot be used for minerals embedded in a rock, but only for a single crystal or mass (students could discuss the reasons for this).

Only the volumes of insoluble minerals can be tested by methods A and B.

Title: P3 Application of classification systems using distinguishing characteristics to identify unknown minerals

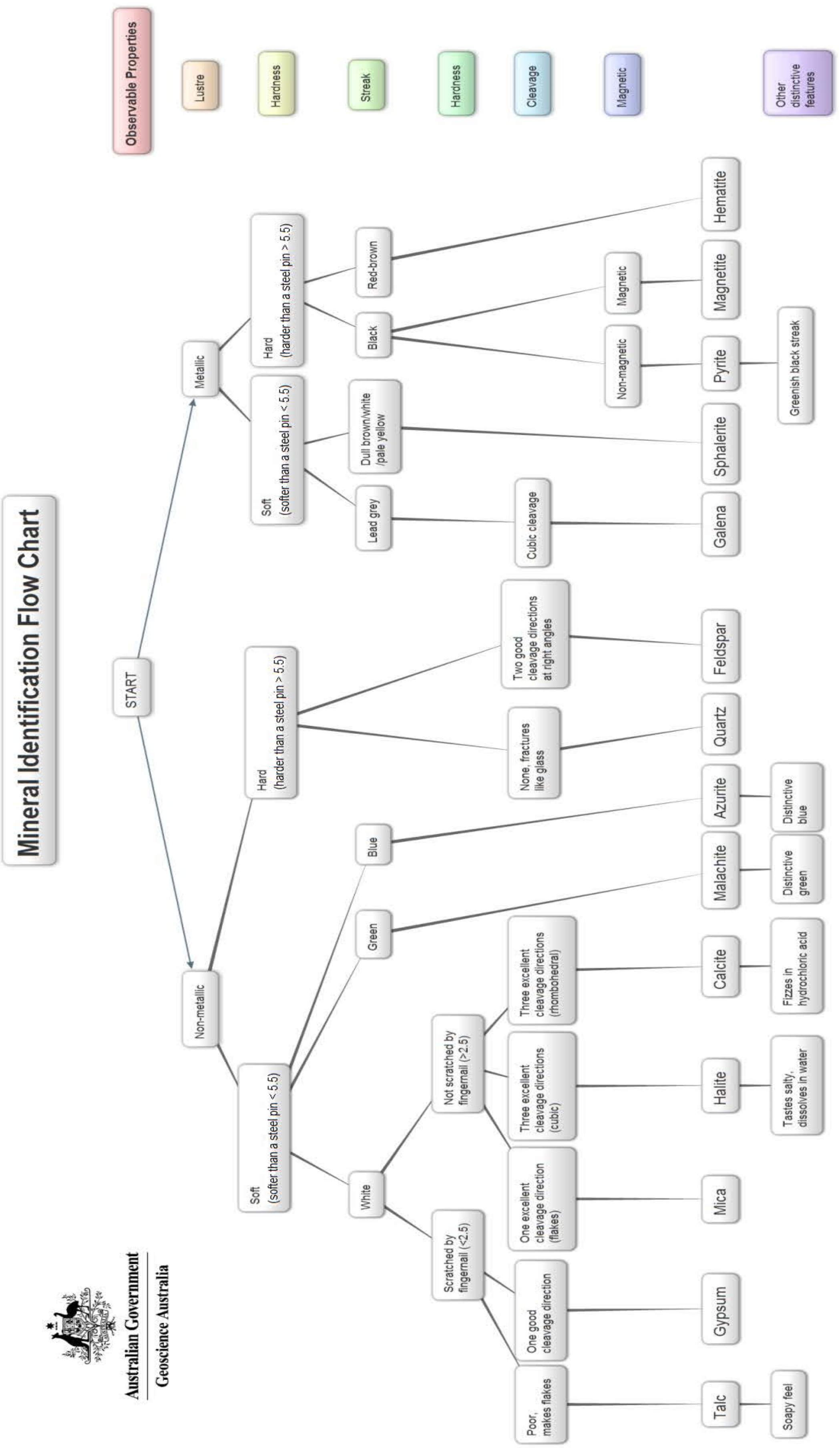
Specification reference: 1.1e

Aim: To apply a classification system using distinguishing characteristics to identify unknown minerals.

Apparatus:
Classification system/identification flow chart for minerals
Samples of unknown minerals

Method:
Following an identification flow chart perform diagnostic tests on minerals in order to identify them.

Teacher/Technician notes:
Learners should follow a classification system/identification flow chart, and perform tests in order to identify a range of minerals. An example of an identification flow chart is given below, but an alternative could be used.
Learners could also devise their own identification flow charts, with other learners trying them out to test how effective they are.



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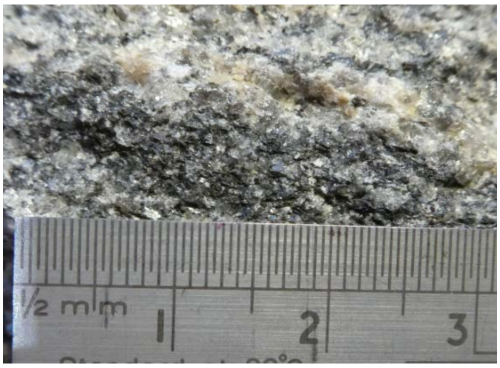
Title: P4 Production of scaled annotated scientific drawings of rock samples from hand samples using a light microscope, or hand lens observation

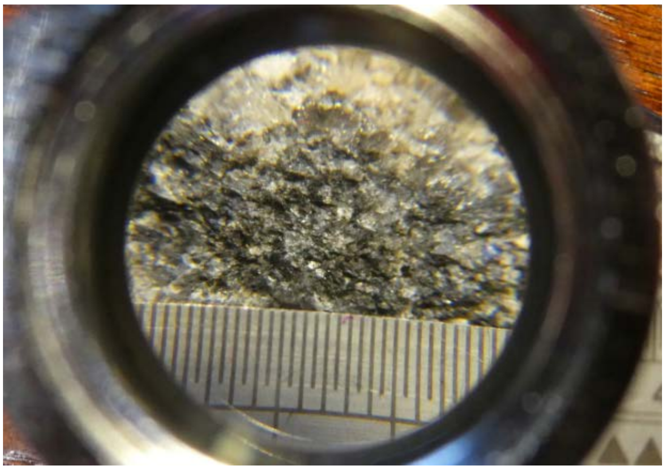
Specification reference: 1.1.g

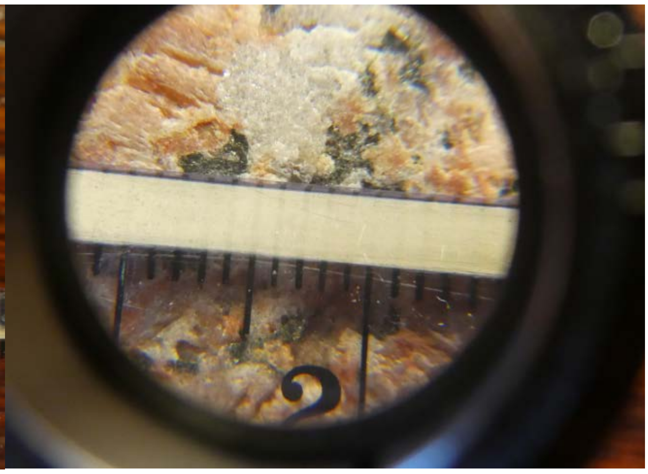
Aim: To produce scaled annotated scientific drawings of rock samples from hand samples using a light microscope, or hand lens observation.

Apparatus:
Hand lens or light microscope
Ruler
A sediment comparator (for sedimentary rocks)
Plain paper
Pencil
A range of igneous, sedimentary and metamorphic rocks

Method:
1. Place the rock under a light microscope or hand lens (if using a hand lens, hold the hand lens in front of one eye, keeping your head up to keep the rock specimen illuminated, and bring the rock into focus in front of the hand lens).
2. If using a hand specimen, hold a ruler in the field of view in the same hand as the hand specimen, thus giving a scale to the rock texture seen. The use of a scale in this manner is called a fiducial scale. N.B. A fiducial marker or fiducial is an object placed in the field of view of an imaging system which appears in the image produced, for use as a point of reference or a measure as illustrated below.



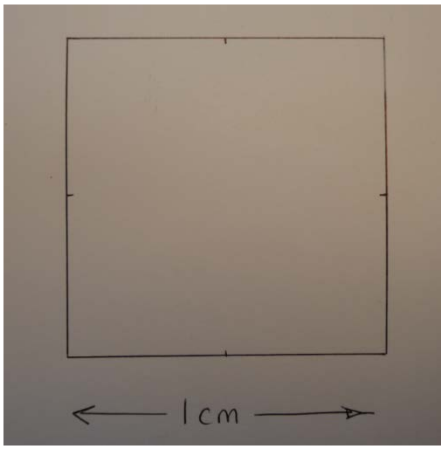


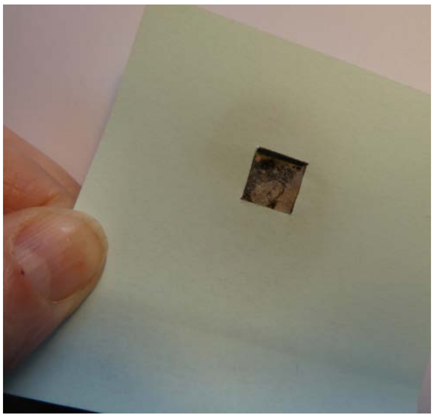


3. Draw the textural features of the rock focusing on:
    - whether the rock is crystalline or clastic
    - crystal/grain sizes
    - range of crystal/grain sizes, sorting
    - shape of crystals/grains
    - foliation; mineral alignment/bedding/crystalline banding.
4. Put a scale on the drawing.
5. Annotate these textural features.
6. Identify and annotate component minerals.
7. Deduce the mode of origin as igneous, metamorphic or sedimentary.
8. Identify the rock.
9. Give the diagram a title.

Teacher/Technician notes:

Learners could be encouraged to draw scaled diagrams drawing the rock texture in a square box with scale markings (to “scale up”) the sizes of the crystals or grains. The size of the box will vary depending on the size of the crystals/grains in the hand specimen.





Learners could select a suitable area to draw by using a frame, (a “Post-It” note with a square cut out, 1cm or 2cm etc dependent on size of crystals/grains and features of the hand specimen).

Learners should draw a range of rocks (igneous, sedimentary, metamorphic) from those listed on the specification and any others that the teacher sees appropriate (for example those linked to field sites visited during the course).
The drawings should be to scale, and also annotated with the textural and mineralogical features (thus linking parts of the specification).
Learners should finish by identifying the rock type.

Title: P5 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

Specification reference: 2.1e

Aim: To produce a 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.

Apparatus:
Hand lens or light microscope
Ruler
A sediment comparator
A range of sedimentary rocks

Method:
1. Select a hand specimen of a sedimentary rock (or an unfamiliar field exposure of sedimentary rock).
2. Describe the texture of the rock:
    - clastic/fragmental/granular
    - grain size (s)
    - grain shape
    - the degree of sorting of the grains.
3. Describe features of the composition of the rock:
    - colour(s)
    - identify the minerals within the rock
    - identify the composition of the cement.
4. Observe and record any macro features in the sedimentary rock specimen such as sedimentary structures or fossil content.

Analysis:
1. Identify the name of the rock using the textural characteristics and compositional information recorded.
2. Refer to appropriate sources of information e.g. AS notes and internet sources, to determine the environment of formation of the rock using the evidence gathered.

Teacher/Technician notes:
Specimens should be selected to cover the list of sedimentary rocks, features and environments stated in section 2.1d, e and f of the specification.
Sediments may be a useful resource (e.g. a range of sands from beach, river, glacial and desert environments).

N.B. A sediment comparator is a useful tool in describing sedimentary rock texture. However it is not permitted equipment in the examinations and learners should be made aware of this.

![eduqas Part of WJEC]

Title: P6 Construction of graphic logs using appropriate scale and symbol sets for unfamiliar geological sequences and exposures to record data relevant to an investigation

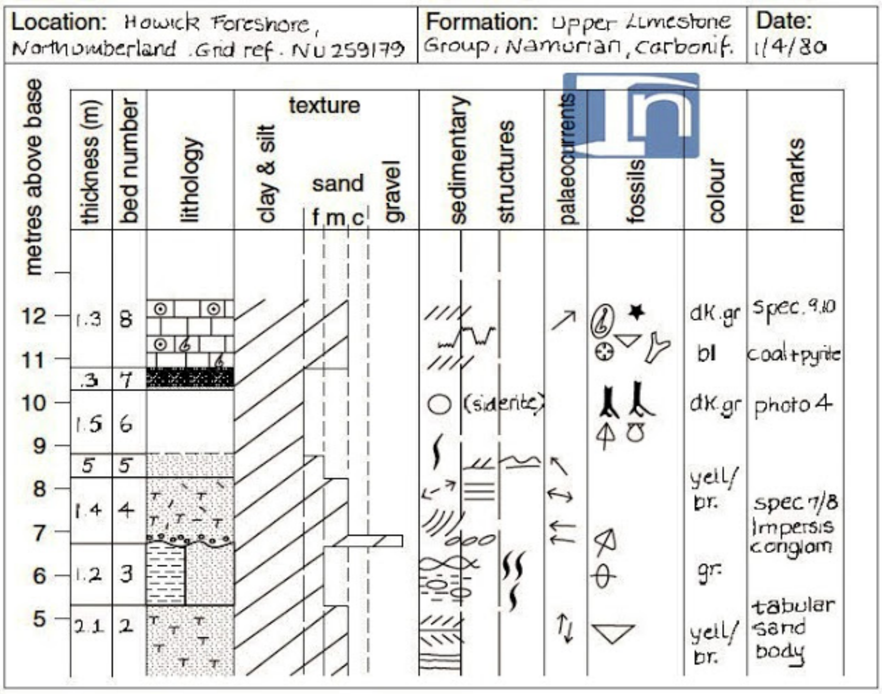
Specification reference: 2.1e

Aim: To construct graphic logs using appropriate scale and symbol sets for unfamiliar geological sequences and exposures to record data relevant to an investigation.

Apparatus:
Tape measure
Sediment comparator
Hand lens
Graphic log template
Graphic log key
Pencil

Method:

1. Select a section of a sedimentary sequence to be logged. If relevant use a sampling method for locating the log, either systematic sampling or random sampling. Ideally the sequence will have continuous exposure. If not it may be necessary to move sideways along the section to find where the beds higher up the sequence are exposed so that a continuous record can be produced.
2. Decide on a vertical scale to be used e.g 1:10 (1 cm to 10 cm).
3. Begin the graphic log at the base of the sequence.
4. Record the following features: bed or rock unit thickness, lithology, grain size, sedimentary structures, colour, fossils and the nature of bed contacts (e.g erosive, gradational or sharp and planar).
5. Other features that may be logged include paleocurrent directions and additional textural features such as grain shape and sorting.



Geology In www.geology.com

Features to be aware of:

Bed or rock-unit thickness
The bed thickness is measured with a tape measure. When the beds are dipping steeply and logging is taking place on a surface oblique to the bedding planes care must be taken to ensure that the true thickness of the beds is recorded.
Where thin beds of the same lithology occur together they can be grouped together into a single unit with one lithology on the log.
Where thin beds of different lithology rapidly alternate, e.g. interbedded sandstones and shales, they can be treated as one unit and notes made of changes in the relative thickness of these beds up the sequence.

Lithology
On the graphic log, lithology is recorded in a column by using an appropriate shading in the key. If two lithologies are thinly interbedded, then the column can be divided in two by a vertical line and the two types of shading entered.

Texture (grain-size)
On the log there should be a horizontal scale for the grain size column. For many rocks this will show mud (clay + silt), sand (divided into fine, medium and coarse) and gravel. Gravel can be divided further if coarse sediments are being logged. Having determined the grain-size of a rock unit, this is marked on the log and the area shaded (the wider the column, the coarser the rock).

Sedimentary structures and bed boundaries
Sedimentary structures within the beds can be recorded in a column by symbols shown in a key. The bed boundaries can be recorded in the lithology column separating one bed from another. These boundaries may be:

- erosive (shown as a wavy/irregular line)
- gradational (shown as a dashed line)
- sharp and planar (shown as a straight line)

Palaeocurrent directions
If required, these can be recorded on the graphic log as an arrow showing the compass direction and the measurements can be recorded separately in a field notebook.

Fossils
Fossils indicated on the graphic log should record the main fossil groups present in the rocks. Symbols which are commonly used are shown in a key and can be placed in the fossil column. The degree of fragmentation of the fossils may be recorded in the 'remarks' column of the graphic log.

Colour
The colour of a sedimentary rock is best recorded by a series of abbreviations
e.g. bl = black, li gr = light grey.

'Remarks' column
This can be used for extra information regarding sedimentary structures, texture, lithology, fossil preservation as well as cross references to photographs or field sketches.

Analysis:
Each bed should be analysed to determine the processes involved in deposition and the environment of deposition of the sedimentary rock contained.
In this way, changes in the environment of deposition up the sequence (over time) can be determined.

Teacher/Technician notes:
A suitable program for drawing and manipulating graphic log data (SEDLOG) can be downloaded free at http://thames.cs.rhul.ac.uk/sedlog/

Graphic logging is basically a list or diary of the rocks and their features in a “standard” format which enables interpretation of processes and environment and any changes.

Graphic logging may be practised in the laboratory prior to it being undertaken on fieldwork by construction of a “mock cliff face”.

A

B

This may be achieved by:

- putting rocks in a length of gutter to build up a sequence (**A**)
  or
- an alternative method (**B)** involves a 1 metre (or other) plastic tube (a suitably reinforced container that once housed a curtain pole is ideal) is filled with sediments of different types (to show a variety of mineralogy, textures and colours). To ensure a sharp, rather than a diffuse boundary between fine sediment overlying coarser sediment, it is best if the finer sediment is initially contained in a see-through plastic bag which prevents settlement into the open pore spaces in the coarser sediment below. With care, suitable sedimentary structures can be achieved – load structures, graded beds, cross bedding, imbricate structures etc.

An example of a graphic log template (AS and A level)

Location: Grid reference:				Formation:				Date:
thickness in metres	bed number	lithology	texture clay and silt | f | m | c | sand | gravel	sedimentary structures	fossils	palaeocurrent direction	colour	remarks/notes

Lithology

Devise suitable symbols to use for any sedimentary rocks/sediments found in the graphic log.

Siliciclastic sediments		Carbonates	Others
Clay/ mudstone	Sandstone (undifferentiated)	Limestone (undifferentiated)	Coal
Shale	Conglomerate	Oolitic limestone	Evaporite
Siltstone	Breccia	Chalk	Volcaniclastic sediment
Devise others as required			

Sedimentary structures

Devise suitable symbols to use for any sedimentary structures found in the sedimentary rocks/sediments.

Cross-bedding	Cross-lamination	Asymmetrical ripple marks	Erosive bed boundary
Graded bedding	Desiccation features	Load/Flame casts	Gradational bed boundary
Parallel Lamination	Symmetrical ripple marks	Flute casts	Sharp/planar bed boundary
Devise others as required			

Fossils

Devise suitable symbols to use for any fossils found in the sedimentary rocks/sediments.

Brachiopod	Coral-colonial	Graptolite	Burrow
Cephalopod	Coral-solitary	Plant	Track/trail
Bivalve	Trilobite		
Devise others as required			

Title: P7 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

Specification reference: 2.1.e

Aim: To use photomicrographs to identify minerals and rock textures of sedimentary rocks in order to identify rock types and to deduce their environment of deposition.

Apparatus:
Photomicrographs or drawings of photomicrographs of a range of sedimentary rocks
Ruler
Mineral data sheet.

Method:
1. Select a photomicrograph of a sedimentary rock.
2. Describe the texture of the rock:
    - clastic/fragmental/granular
    - grain size (s)
    - grain shape
    - the degree of sorting of the grains.
3. Describe features of the composition of the rock:
    - identify the minerals within the rock
    - identify the composition of the cement.

Analysis:
1. Identify the name of the rock using the textural and compositional characteristics.
2. Refer to appropriate sources of information e.g. AS notes, internet sources to determine the environment of formation of the rock using the evidence of mineralogy and texture.

Teacher/Technician notes:
If petrological microscopes are available learners could be provided with thin sections of a variety of rock types which could be drawn and annotated.
Alternatively learners could draw and annotate images of thin sections using internet sources or learners could be provided with copies of images for annotation.
Websites containing thin section images of a variety of rocks include:

http://www.earthscienceeducation.com/virtual_rock_kit/DOUBLE%20CLICK%20TO%20START.htm

https://wwwf.imperial.ac.uk/earthscienceandengineering/rocklibrary/identify.php?itype=4&istep=1

Images should be selected to cover the suggested list of sedimentary rocks in section 2.1e of the specification.

Title: P8 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

Specification reference: 2.2.b

Aim: To produce 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.

Apparatus:
Hand lens or light microscope
Ruler
A range of igneous rocks

Method:
1. Select a hand specimen of an igneous rock (or an unfamiliar field exposure of igneous rock).
2. Describe the texture of the rock:
   - crystalline
   - crystal size (s): coarse (>3mm), medium (1-3mm), fine (<1mm)
   - other textural features: equicrystalline, porphyritic, vesicular, glassy, fragmental
   - crystal shape: euhedral, subhedral, anhedral.
3. Describe and identify the minerals within the rock
4. Observe any macro features from the igneous rock specimen/field exposure e.g. pillow structures, aa/pahoehoe surfaces, columnar joints.

Analysis:
1. Identify the name of the rock using the textural characteristics and mineralogy.
2. Refer to appropriate sources of information e.g. AS notes, internet sources to determine the cooling history of the rock using the evidence from the texture.

Teacher/Technician notes:
Specimens should be selected to cover the suggested list of igneous rocks in the specification section 2.2b. Other specimens may be used.

Title: P9 Use of photomicrographs to identify minerals and rock textures of igneous rocks to identify rock type and to deduce their cooling history

Specification reference: 2.2.b

Aim: To use photomicrographs to identify minerals and rock textures of igneous rocks to identify rock type and to deduce their cooling history.

Apparatus:
Photomicrographs or drawings of photomicrographs of a range of igneous rocks
Ruler
Mineral data sheet

Method:
1. Select a photomicrograph of an igneous rock.
2. Describe the texture of the rock:
    - crystalline
    - crystal size (s): coarse (>3mm), medium (1-3mm), fine (<1mm)
    - other textural features: equicrystalline, porphyritic, vesicular, glassy, fragmental
    - crystal shape: euhedral, subhedral, anhedral
3. Describe and identify the minerals within the rock.

Analysis:
1. Identify the name of the rock using the textural characteristics and mineralogy.
2. Refer to appropriate sources of information e.g. AS notes, internet sources to determine the cooling history of the rock using the evidence from the texture.

Teacher/Technician notes:
If petrological microscopes are available learners could be provided with thin sections of a variety of rock types which could be drawn and annotated.
Alternatively learners could draw and annotate images of thin sections using internet sources or learners could be provided with copies of images for annotation.
Websites containing thin section images of a variety of rocks include:

http://www.earthscienceeducation.com/virtual_rock_kit/DOUBLE%20CLICK%20TO%20START.htm

https://wwwf.imperial.ac.uk/earthscienceandengineering/rocklibrary/identify.php?itype=4&istep=1

Images should be selected to cover the suggested list of igneous rocks in the specification section 2.2b.

Title: P10 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

Specification reference: 2.2.g

Aim: To produce 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.

Apparatus:
Hand lens or light microscope
Ruler
A range of metamorphic rocks

Method:
1. Select a hand specimen of a metamorphic rock (or an unfamiliar field exposure of metamorphic rock).
2. Describe the texture of the rock:
   - crystalline
   - foliated, including type of foliation (slaty cleavage, schistosity and gneissose banding) or non-foliated
   - crystal size (s)
   - porphyroblastic or granoblastic
   - crystal shape
3. Describe and identify the minerals within the rock.
4. Observe any macro features from the metamorphic rock.

Analysis:
1. Identify the name of the rock using the textural characteristics and mineralogy.
2. Refer to appropriate sources of information e.g. AS notes, internet sources to determine the temperature and pressure conditions of the formation of the rock using the evidence of mineralogy and texture.

Teacher/Technician notes:
Specimens should be selected to cover the suggested list of metamorphic rocks in the specification section 2.2g.

Title: P11 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

Specification reference 2.2g

Aim: To use 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.

Apparatus:
Photomicrographs or drawings of photomicrographs of a range of contact and regional metamorphic rocks
Ruler
Mineral data sheet

Method:
1. Select a photomicrograph of a metamorphic rock.
2. Describe the texture of the rock:
    - crystalline
    - foliated, including type of foliation (slaty cleavage, schistosity and gneissose banding) or non-foliated
    - crystal size (s)
    - porphyroblastic or granoblastic
    - crystal shape.

3. Describe and identify the minerals within the rock.

Analysis:
1. Identify the name of the rock using the textural characteristics.
2. Refer to appropriate sources of information e.g. AS notes, internet sources to determine the temperature and pressure conditions of formation of the rock using the evidence of mineralogy and texture.

Teacher/Technician notes:
If petrological microscopes are available learners could be provided with thin sections of a variety of rock types which could be drawn and annotated.
Alternatively learners could draw and annotate images of thin sections using internet sources or learners could be provided with copies of images for annotation.
Websites containing thin section images of a variety of rocks include:

http://www.earthscienceeducation.com/virtual_rock_kit/DOUBLE%20CLICK%20TO%20START.htm

https://wwwf.imperial.ac.uk/earthscienceandengineering/rocklibrary/identify.php?itype=4&istep=1

Images should be selected to cover the suggested list of metamorphic rocks in the specification section 2.2g.

Title: P12 Location of geological features onto a base map

Specification reference: 2.3.b

Aim: To locate geological features in the field onto a base map using traditional navigation and basic field survey skills but without the use of GPS.

Apparatus:
Simple base map of field area
Compass
Pencil

Method:
1. Determine the distance of a geological feature from prominent landmark e.g, a headland, river or bridge by measurement or by pacing. (This can only be undertaken if learners have calculated their typical stride length prior to fieldwork.)

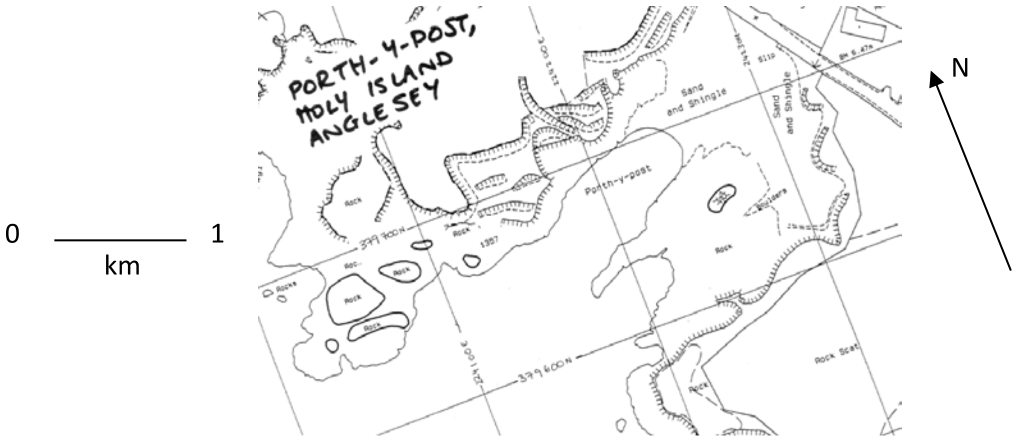
2. Determine the direction of a geological feature from prominent landmarks by taking bearings using a compass as follows:
   - Standing at the geological feature, point the direction of travel arrow of the compass (the long dimension of the compass) at the landmark
   - Turn the compass dial until the North arrow in the base plate of the dial lies under the red "hovering North arrow"
   - Place the compass on the map so that the orienting lines within the base of the compass dial are parallel to the map's North-South lines (meridians)
   - Move the compass across the map so that the top corner of one long edge ends at the landmark, keeping it aligned with the map's meridians.
   - Draw a feint line on the map along the edge of the compass from the landmark. The geological feature is somewhere along this line.
   - If a bearing is taken to a second landmark, and the process repeated, the geological feature should be at the point where the two feint lines meet on the map.

3. Locate the geological feature onto the base map using approximate distances and bearings from prominent landscape features.

Information on how to take a bearing can be found at:
https://www.youtube.com/watch?v=BADUq3Maqbo

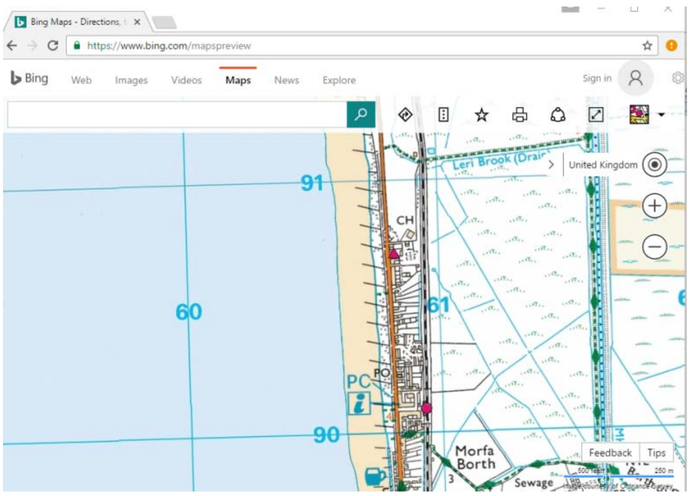
Analysis:
None required.

Teacher/Technician notes:
Simple base maps of field areas should be produced by the teacher prior to fieldwork activity.
These can be simple hand drawn maps, or derived from OS maps (or electronic versions) but all should have a scale and orientation.



Maps can be derived from looking at map views online (or satellite views) or from traditional paper maps.
Electronic maps are available from Google Earth and Google Maps and Bing Maps. Although the more useful maps have OS map data (e.g. contour lines).

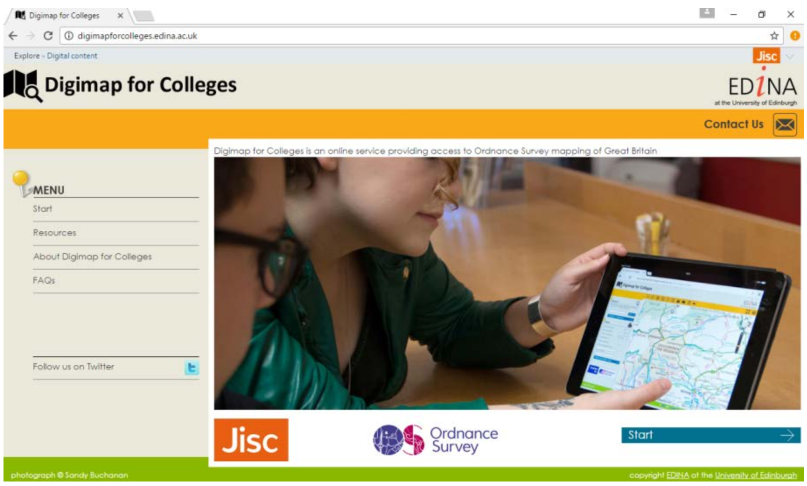
Bing https://www.bing.com/mapspreview
Ordnance Survey view should be selected (tool bar on the top right hand side), scale appears in the bottom right hand corner, and grid lines give orientation. Note that the grid lines often appear at an angle.
“Screen shots” or use of the “snipping tool” can give good base maps.



Microsoft bing maps www.bing.com/mapspreview

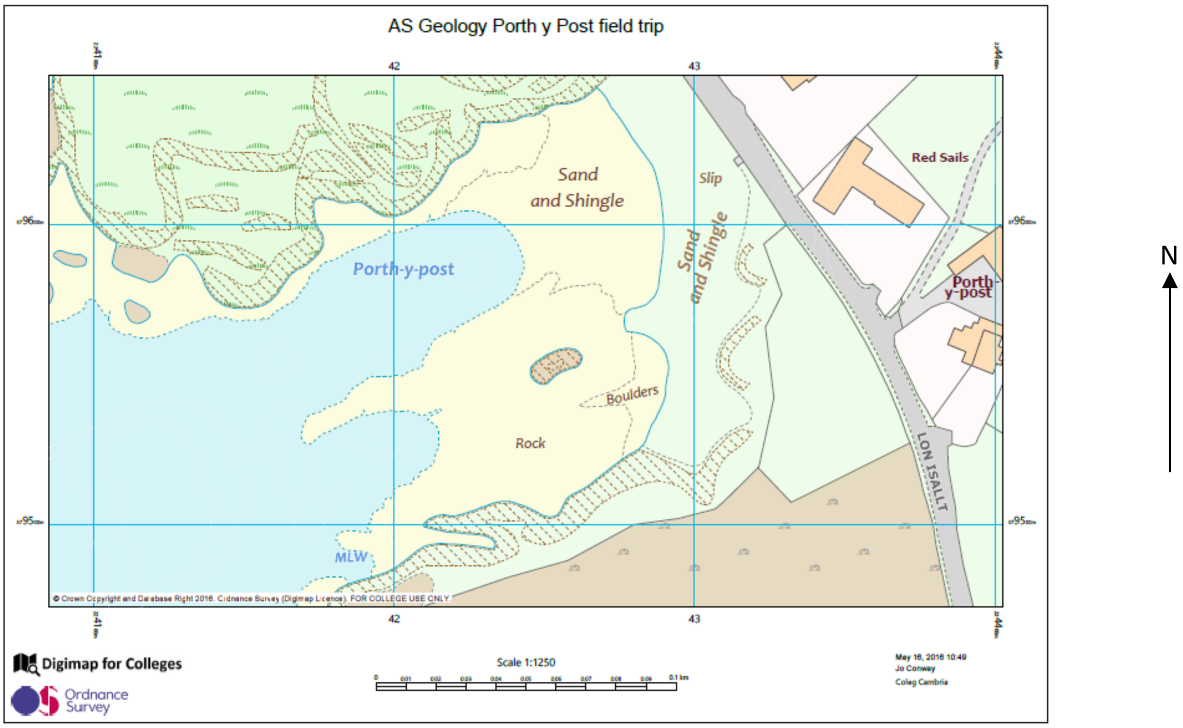
It may be necessary to number the grid lines if they are not prominently labelled on the selected section.

Many FE colleges have subscribed to the Edina program and have access to Digimap. http://digimapforcolleges.edina.ac.uk/ However this is usually only available within your college.



Digimap for Colleges http://digimapforcolleges.edina.ac.uk/

Digimap is a range of Ordnance Survey digital maps, covering the whole of GB. Included are the most detailed maps OS make which show building outlines. These maps are suited to being used for local area studies, studying land use on the high street, locating businesses or planning a new construction site. They are digital versions of traditional OS maps that are commonly used for hill walking and outdoor activities, as well as street-level, road-atlas style and regional maps.
The maps are complemented by a range of tools that allow you to enhance the maps. Measurement tools, Annotation Tools (you can use to add points), Save (save any maps that you create to come back to later) and Print (to create printable PDF or JPG maps). Printable maps can be printed to make hard copies, saved to a computer drive.



Digimap for Colleges http://digimapforcolleges.edina.ac.uk/

Grid lines are parallel with the edge of the paper/box that the map appears in.
And scale bars are very sharp and easily used for distances.
“Screen shots” are useful for showing maps at alternative scales.

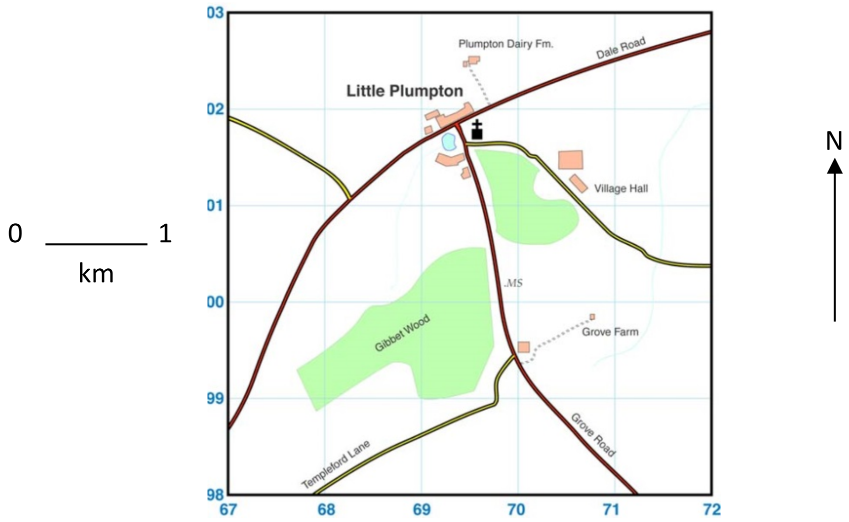
Title: P13 Identification of the location of geological features in the field using six figure grid references on maps

Specification reference: 2.3.b

Aim: To identify the location of geological features in the field using six figure grid references on maps.

Apparatus:
Geological features located on a map showing grid squares.

Method:
1. Check that the map has grid lines running up and down the map. (These lines are Eastings and increase in number the further to the right or East, assuming that North is orientated up the map.)
2. Check that the map has grid lines running across the map. (These lines are Northings and increase in number the further up the map, or North, assuming that North is orientated up the map.)
3. Read the numbers along the bottom of the map first (the Eastings) and the numbers up the side of the map second (the Northings).
4. Locate a geological feature in a grid square. Give a four figure grid reference for that square as a whole, with the Easting and Northing values defining the bottom left hand corner of the square e.g. A geological feature adjacent to the Mile Stone MS in the map below is within grid square 6900.
5. To locate a more precise location of a geological feature within a grid square, a six-figure grid reference is used e.g. the geological feature adjacent to the Mile Stone MS in the map below is at 698002, $\frac{8}{10}$ of the way across and $\frac{2}{10}$ of the way up grid square 6900.
6. The six-figure grid reference for geological features should be recorded in a field notebook and on any field sketches of the features.



Wikimedia Creative Commons http://bit.ly/2j7ElUC

Analysis:
None required.

Title: P14 Production of scaled, annotated field sketches at unfamiliar field exposures to record data relevant to an investigation

Specification reference: 2.3b

Aim: To produce scaled, annotated field sketches at unfamiliar field exposures to record data relevant to an investigation.

Apparatus:
Field notebook or plain paper large enough to be able to include the required amount of drawn and written detail
Pencil (soft) and eraser
Clipboard / something to rest on
Metre rule or equivalent (to determine scale)
Compass (to determine orientation)

Method:
1. Consider the purpose of the field sketch, i.e. what is to be shown – decide on what is important to include and make prominent in the sketch. Make a list of terms first, then draw.
2. Find a comfortable sheltered position to work from, safe and easily accessible, (and gives the same perspective as the secondary data if needed), and is free from obstruction.
3. Identify a frame for the sketch – holding up a cardboard frame may help to do this. Alternatively define what will form the top and bottom of your sketch e.g. the skyline or top of a cliff, and the base of a cliff.
4. Orientate the paper so that it mirrors the dimensions of the sketch to be drawn e.g. orientate the paper in “landscape” for a sketch that will be wider than tall.
5. Draw a frame, or the features that will form the top and bottom of the sketch, onto the paper.
6. Draw the main features of the sketch which form the most prominent or important geological features first.
7. Draw geological features of finer detail.
8. Add labels and annotations for the geological features.
9. Add a scale for the field sketch.
10. Label the direction, bearing, grid reference and a short written description of the ‘view’.

Considerations

Scale – this can be difficult to assess, particularly when sketching a large landscape area. Starting the sketch with the things furthest away and working towards you will help. Also, add labels to show things of known height (refer to map of the area to find this).
Slope – drawing the correct angle of a slope can be problematic. Try holding a pencil away from you, towards the slope and then transfer it to the paper.
Weather – adverse conditions will have an immediate, preventative effect on the ability to carry out a field sketch!
Use photography to **compliment** the field sketch. Photos can be used to add detail to the sketch later, which there may not have been time to include or suitable conditions to achieve in the field.
The field sketch needs to be ‘fit for purpose’ to add value to your investigation - this takes some thought and consideration. It’s very easy to just ‘knock out’ the odd quick sketch which adds nothing to an investigation.

Labels should be used to pick out the main features, and **annotations** to comment on certain aspects in order to bring out the main 'message' to be conveyed.

Analysis:
None required

Teacher/Technician notes:

Learners may practice field-sketching in the classroom prior to fieldwork.

Task 1: In class situations, learners could use photographs to be given practice in how to produce a large field sketch, possibly using tracing paper or a transparency to help. See example below.

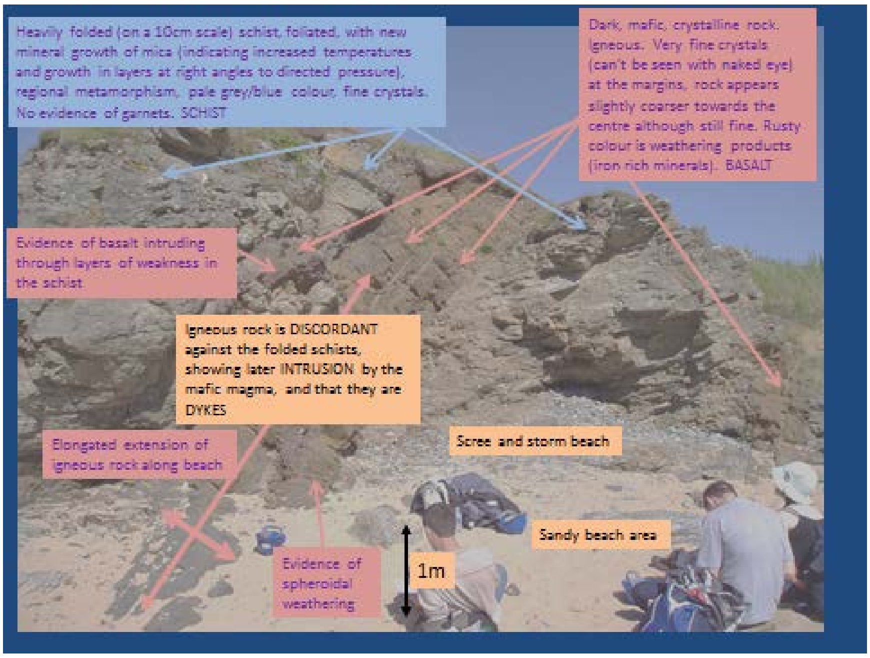
It might look something like this when finished.

From the following description, try to label and annotate your field sketch:

"the area was a beach, with a small shingle storm beach at the top and some vegetation on the area behind. The exposure faced east. In the middle of the exposure there were two basalt igneous intrusions cutting across the country rock (which was a heavily folded schist). The contacts were sharp. There was another dyke to the right of the exposure. The dykes were more coarsely crystalline towards their middles but still fine."

Labels/annotations might look something like this when it is finished.

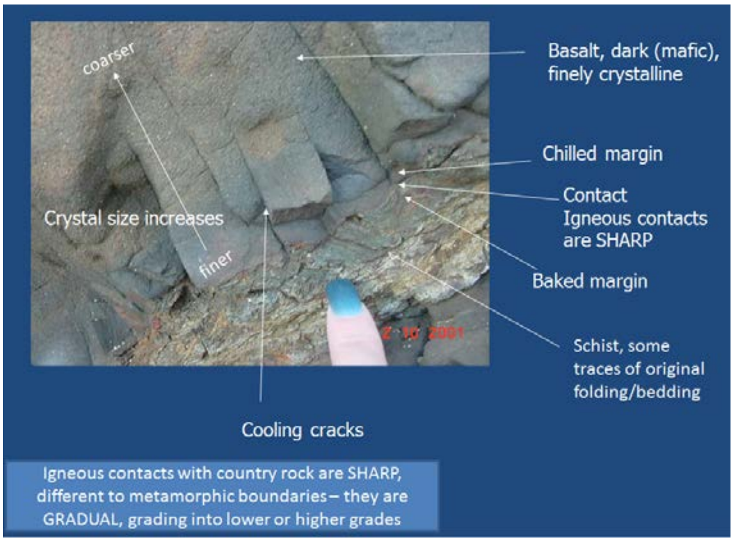
North



South

Task 2: In class situations, learners could use photographs to be given practice in how to produce a small detailed sketch, possibly using tracing paper or a transparency to help. See example below.
Using the photograph below produce a detailed interpretation of the contact between the country rock and the igneous contact, drawing and annotating a field sketch, or annotating the photograph.

It could look something like this.



Information on how to construct field sketches can be found at

http://www.esta-uk.net/fieldworkskills/tips.htm

Title: P15 Measurement of dip and strike elements: dip angle, dip and strike directions of planar surfaces, relevant to an investigation

Specification reference: 2.3b

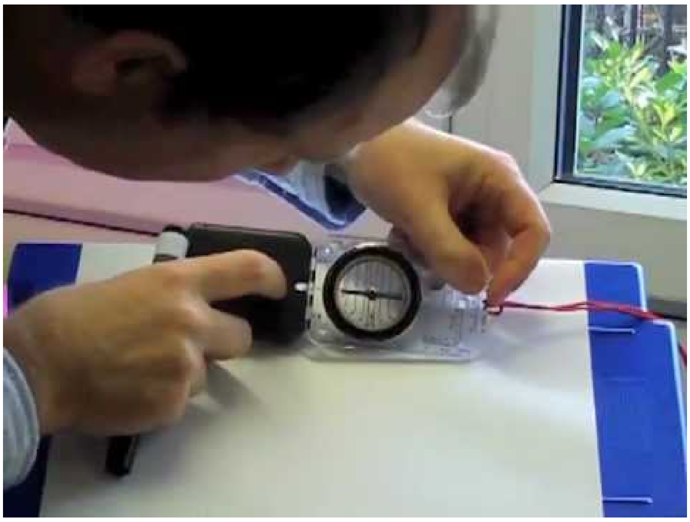
Aim: To measure dip and strike elements: dip angle, dip and strike directions of planar surfaces, relevant to an investigation.

Apparatus:
Compass clinometer (or separate compass and clinometer)

Method:

1. Strike direction

- Set the compass clinometer to East-West by turning the bezel so that the values 90 and 270 intersect the markers on the compass which are often a pair of fluorescent dashes. This puts the compass clinometer in clinometer mode.
- Hold the clinometer vertically and place it on its long edge on the plane (e.g. a bedding plane).
- Move the clinometer round, on its long edge, keeping it vertical, until the clinometer reading is zero.



Havering sfc YouTube http://bit.ly/2k6DqIC

- Draw a line on the plane, using chalk in the field. This line is the direction of strike.
- Turn the compass clinometer horizontal, so that it is now in compass mode.
- Point the long axis of the compass along the chalk line representing the direction of strike.

Geology In www.geology.com

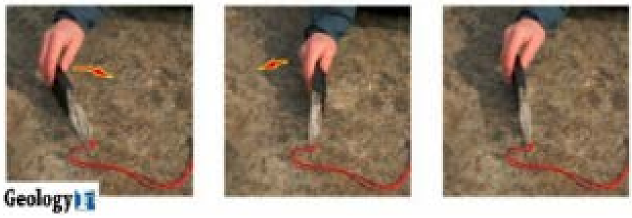
- Turn the dial of the compass (the bezel) so that red suspended arrow overlies the red arrow in the base of the bezel.

Geology In www.geology.com

- Read off the direction of the strike on the rim of the bezel where the rim intersects the “marker” which is often a fluorescent “dash”. There are two of these and it does not matter which is used. They will be 180 degrees apart.
- Record the direction of strike as a 3 digit number. If the directions of strike are 8° and 188°, this is recorded as either 008°or 188°.

2. Angle of dip

- Put the compass clinometer into clinometer mode again. (Set the compass clinometer to East-West by turning the bezel so that the values 90 and 270 intersect the markers on the compass which are often a pair of fluorescent dashes.)
- Hold the clinometer vertically and place it along its long edge on the plane. Move the clinometer round, on its long edge, keeping it vertical and in contact with the rock, until the clinometer reaches its maximum reading. This is the true dip reading and happens when the clinometer is pointing down the plane at 90 degrees to the direction of strike.



Geology In www.geology.com

- Read off the dip angle by reading off where the arrow, which hangs down inside the bezel, intersects the scale in the inside of the bezel. The value will be between 0 and 90.
- Record the angle of dip as a two digit number e.g. 42°.

3. Direction of dip

- The direction of dip will be at a bearing of 90° from the direction of strike.
- It is the direction to which the plane loses height, the direction to which the angle of dip reading was taken.
- It can be recorded as a compass direction e.g. S, W, NW, SE etc.

A complete dip and strike reading for a planar surface such as a bedding plane should be recorded in the following way.

Strike direction (3 digits)/Dip angle (2 digits)/Dip direction (a compass direction)

e.g. 188/42/E

4. Apparent Dip

On occasions it is not possible to place a compass clinometer on a 3-dimensional outcrop of a planar surface and only a 2-dimensional view of a dipping plane is visible e.g.in the face of a cliff. In such cases a plane can be seen to be dipping but it is not possible to determine the direction of strike of the plane, nor therefore to determine the true dip direction.
In these situations all that can be recorded is the angle at which the plane appears to be dipping (recorded as 2-digits) and the direction to which the plane appears to be dipping (recorded as a 3-digit bearing). These readings record the Apparent Dip of the plane rather than the True dip of the plane and this must be noted alongside the readings.

e.g. 32/185 Apparent Dip

Repetition of readings: Planar surfaces in geology are often irregular. For this reason one reading of dip and strike may not be representative of a planar surface or of a series of planar surfaces.
It may be worth taking more than one reading of dip and strike on a plane or on a concordant series of adjacent planes in order to increase the accuracy of measurements.

Sampling: Where a series of dip and strike readings are to be taken for an investigation into a sequence of folds for example, a sampling method should be used to ensure that the readings are representative of those required for the investigation. The pros and cons of various sampling methods (random, systematic, stratified) should be considered before a sampling strategy is chosen.

Analysis:
Analysis of the data relevant to an investigation

Teacher/Technician notes
Video examples of how to take dip angle, strike direction and dip direction can be found on Youtube e.g.
https://www.youtube.com/watch?v=FbXhooadhZw

https://www.youtube.com/watch?v=VCN2q6xwTNk

and also on video clips at
http://www.esta-uk.net/fieldworkskills/video%20clips.htm

Title: P16 Application of classification systems using distinguishing characteristics to identify unknown fossils

Specification reference: 3.1d

Aim: To apply classification systems using distinguishing characteristics to identify unknown fossils.

Apparatus:
Classification system/identification flow chart for fossils
Specimens or photographs of unknown fossils

Method:
Learners devise their own identification flow charts using fossils or photographs of a range of examples within individual fossil groups.
The flowcharts are then used by other learners to identify a range of fossils within one fossil group.

Teacher/Technician notes:
Learners devise their own identification flow charts using fossils or photographs of a range of examples within individual fossil groups.
The flow charts should make use of variations in the stated hard parts or additional hard parts for fossil groups listed in the specification.

e.g. A range (4 or 5) brachiopod specimens could be identified using variation in shell shape, symmetry, features of pedicle or brachial valves, the presence or absence of a foramen and relative length and shape of the hinge line.
Suitable brachiopods could include the following:
Spirifer, Rhynchonella, Productus, Leptaena, Lingula, Kirkidium.

e.g. A range of trilobites could be identified from photographs using a flow chart which makes use of some or all of the following:

- relative sizes of cephalon, thorax and pygidium
- the relative size of the glabella
- the presence or absence of eyes
- the relative size, shape or location of eyes
- The presence or absence of genal spines
- The relative length of genal spines
- The presence or absence of thoracic spines
- the presence or absence of a spine on the pygidium
- the number of thoracic segments
- the number of segments in the pygidium.

A series of photographs are included for this exercise. Others could be used.

Cheirurus

Wikimedia Creative Commons http://bit.ly/2jqm9Wd

Bellacartwrightia

Flickr Creative Commons http://bit.ly/2ieukaF

Isoprusia

Flickr Creative Commons http://bit.ly/2jyOSMV

Isotelus

Wikimedia Creative Commons http://bit.ly/2jisPqa

Dalmanites

Wikimedia Creative Commons http://bit.ly/2j3GKmT

Zlichovaspis

Wikimedia Creative Commons http://bit.ly/2jyV7jG

Calymene

Wikimedia Creative Commons http://bit.ly/2ifQ1ni

Onnia

Wikimedia Creative Commons http://bit.ly/2jqiqIp

Title: P17 Production of scaled, annotated scientific drawings of fossils, using a light microscope, or hand lens observation

Specification reference: 3.1d

Aim: To produce scaled, annotated scientific drawings of fossils, using a light microscope, or hand lens observation.

Apparatus:
Hand lens or light microscope
Ruler
Plain paper
Soft pencil and eraser
A range of fossils

Method:
1. Place the fossil in a position which offers the best view of the distinctive features of the fossil.
2. If appropriate, plan to draw more than one view of the fossil from differing orientations.
3. For observation of finer details a light microscope or hand lens should be used. (If using a hand lens, hold the hand lens in front of one eye, keeping your head up to keep the fossil illuminated, and bring the fossil into focus in front of the hand lens.)
4. Draw the key features of the fossil focusing on:
    - The overall shape, considering relative length and height so that the fossil does not appear too short or too elongate in either dimension
    - The location/size/shape of major features
    - The number and shape of minor features.
5. Put a scale on the drawing.
6. Label or annotate the major and minor features.
7. Identify the fossil.
8. Give the diagram a title.

Analysis:
None required.

Teacher/Technician notes:
Labels/annotations should include those listed hard parts for relevant fossil groups in the specification section 3.1d.

Title: P18 The application of one or more criteria of relative age (evolutionary change in fossils, superposition of strata, unconformities, cross-cutting relationships, included fragments, way-up criteria) in the field to place geological events in relative time sequences

Specification reference 3.2a

Aim: To determine the relative age of geological events in the field.

Apparatus:
Field note book
Pencil
Other relevant field apparatus e.g. hand lens

Method:
At various geological outcrops make notes and/or field sketches to record observations which will enable the relative age of geological events to be determined.

These events may include:

- deposition of a range of sedimentary rocks
- extrusion of igneous rock
- intrusion of igneous rocks
- folding
- faulting
- erosion
- metamorphism

Analysis/Conclusion:
Using evidence collected in the field, a range of geological events should be put into relative time sequence using one or more criteria of relative age (evolutionary change in fossils, superposition of strata, unconformities, cross-cutting relationships, included fragments, way-up criteria).
The relative time sequence which has been determined should be fully justified from the evidence collected.

Evaluation:
The degree of certainty of the decisions made regarding relative age of geological events should be considered and reasons for any uncertainty should be discussed. Further evidence that could be sought to remove any uncertainties should be proposed and justified.

Teacher/Technician notes:
It is not expected that learners will have necessarily seen all of these relative dating criteria on their fieldtrips.

Learners should have the opportunity to explore relative dating on more than one occasion in the field.

Title: P19 Measurement of densities of representative samples of Earth layers (e.g. granite, basalt)

Specification reference: 4.1a

Aim: To measure densities of representative samples of Earth layers (e.g. granite, basalt).

Apparatus:
Samples of rocks representative of Earth layers such as granite, basalt and peridotite.
Electronic balance
Water
Graduated (Measuring) cylinder

Method:
1. Select a rock sample.
2. Determine the mass of the sample using an electronic balance. Record the result.
3. To determine volume there are 3 possibilities

A. Immerse the rock sample in the water in the graduated cylinder.
Measure how much the water rises (in ml). Record the result.
Convert to cm^3. ($1ml=1cm^3$); record the result.

B. Place a beaker of water on a balance, zeroing the reading scale.
Suspend the rock sample on a thin thread and record the balance reading. (It is important to suspend the sample in water and not to let it rest on the bottom of the beaker or touch the sides.)
This measurement (recorded in grams) can be converted to a volume for the density calculation ($1g = 1cm^3$).

C. Where the rock sample has a regular shape e.g. cuboid, the volume may be determined directly by measuring the length, width and height of the sample.

4. Repeat the process for samples of other rocks representative of Earth layers.

Analysis:

1. Calculate the density of the rock samples using the formula $\text{Density} = \dfrac{\text{Mass}}{\text{Volume}}$.
2. Compare the density values you have calculated with published results.
3. Discuss possible reasons for any discrepancies found with published results.

Title P20: Investigation of the relationships between earthquake data (focal depth, magnitude and distance from plate boundaries) using data on Google Earth^{TM}

Specification reference: 4.2b

Aim: To Investigate the relationships between earthquake data (focal depth, magnitude and distance from plate boundaries) using data on Google Earth^{TM}.

Apparatus:
Google Earth Files on computer

Preparation:

1. Download and install **Google Earth** (https://www.google.com.earth/download).

2. Download and install the KML file "**Tectonic Plate Boundaries**" from:

- **Google Earth/KML Files – USGS Earthquake Hazard Program**. (https://earthquake.usgs.gov/learn/kml.php).

3. Download and install the KML earthquake data file from:

- **Google Earth/KML Files – USGS Earthquake Hazard Program**. (https://earthquake.usgs.gov/learn/kml.php)
- Select "**Real-Time Earthquakes**" option

or

- direct from (https://earthquake.usgs.gov/earthquakes/feed/v1.0/kml.php).

4. There are a number of choices (as of December 2016).

Recommended is:

- **Past 30 Days M2.5+ Earthquakes** (automatic feed – updates every 15 minutes)
- Within this there are options for earthquake epicentres to be coloured by **age** or **depth** (both recommended to be downloaded).

Method:

1. Select a suitable plate boundary to investigate subduction (e.g. Nazca – South American plate subduction) or not (e.g. Transform – San Andreas Fault).

2. Using a suitable sampling technique (if required – depending upon the number of earthquakes available), select individual epicentres and record two variables:

- **depth** (obtained by clicking on the epicentre)
- **distance** to the plate boundary on the surface (e.g. trench, mid ocean ridge, transform fault).
  This can be measured (using the *ruler* from the menu bar) from the epicentre at right angles to the plate boundary or parallel to the direction of relative motion of the plate as indicated – this could lead to good evaluation on the merits of either.

  Ideally a minimum of 30 should be recorded for significant analysis.

(Note: a random or systematic sample can be undertaken on data coloured by age (all the same colour) or a stratified sample on data coloured by depth. In reality, all data may have to be collected if data points are limited, though discussing the options is a good educational experience.)

Analysis:

1. Data can be plotted onto a scatter graph to show correlation. Find the best fit line by eye (or by mathematics – slope of a straight line).

2. Discuss the degree of correlation from observation of the scatter diagram by eye.

3. Conclusions; A comparison of contrasting plate boundaries is very profitable e.g. South America v San Francisco.

Evaluation:

A critical evaluation of the data collection and analysis could be undertaken, in particular the sampling method and the measurement from the epicentre to the plate boundary. (Where actually is the plate boundary on the surface? Is this significant at this scale? Should measurement be at 90^{o} to plate boundary or parallel to the direction of plate movement? Is this significant at this scale?)

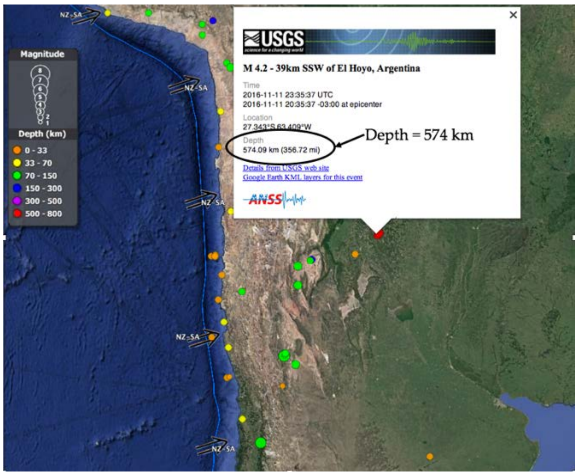
Additional options:

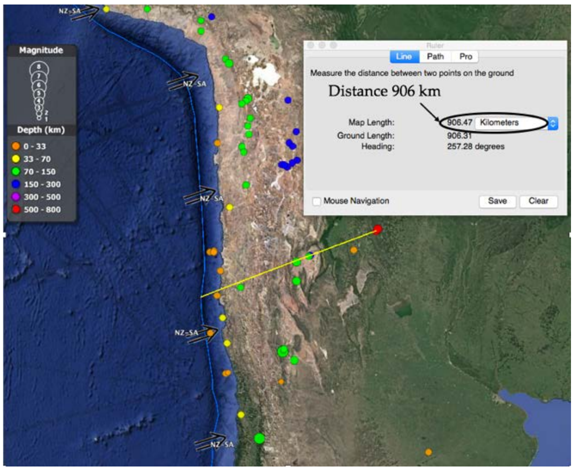
Is there any correlation between other variables – e.g. magnitude and depth, magnitude and distance from plate margin?

Teacher/Technician notes:

Screen shots (5th December 2016)

Nazca Plate/South American subduction earthquakes >2.5





www.google.com/earth

Scatter Graph of the relationship between depth of earthquake foci and the distance of epicentres from the Peru–Chile Trench indicating subduction at a convergent plate boundary.

(Data selected from Google Earth on 6th December 2016)