WJEC Eduqas GCE A LEVEL GEOLOGY

For teaching from 2017
For award from 2019

GCE A LEVEL GEOLOGY

SUMMARY OF ASSESSMENT

Component 1: Geological Investigations
Written examination: 2 hours 15 minutes
35% of qualification

Section A: Two stimulus response questions requiring short and structured answers.

Section B: An investigation of the geology of an area shown on an accompanying simplified geological map, involving

- the interpretation of hand specimens and photographs of minerals, rocks and fossils
- map interpretation and cross-section construction
- the completion of questions using short, structured and extended answers.

Component 2: Geological Principles and Processes
Written examination: 1 hour 45 minutes
30% of qualification

Six stimulus response questions requiring short, structured and extended answers.

Component 3: Geological Applications
Written examination: 2 hours
35% of qualification

Section A: **Geohazards**. Two stimulus response questions requiring short and structured answers.

Section B: **Geological map applications**. An investigation of the geology of an area shown on a Geological Survey map extract using stimulus response questions requiring short, structured and extended answers.

Section C: Learners answer questions on **one option** from a choice of three. Each comprises three questions requiring short, structured and extended answers.

- **Quaternary Geology**
- **Geological Evolution of Britain**
- **Geology of the Lithosphere**

Practical Endorsement
Non-exam assessment

Assessment of practical competency.
Reported separately and not contributing to final grade.

This linear qualification will be available for assessment in May/June each year. It will be awarded for the first time in summer 2019.

Ofqual Qualification Number (listed on The Register): 603/0859/X

Qualifications Wales Designation Number (listed on QiW): C00/1174/5

GCE A LEVEL GEOLOGY

1 INTRODUCTION

1.1 Aims and objectives

The WJEC Eduqas A level in Geology provides a comprehensive coverage of the knowledge and understanding required for the study of the Earth, its structures, evolution and dynamics. The core aspects of this specification introduce eight geological concepts:

- elements, minerals and rocks
- surface and internal processes of the rock cycle
- time and change
- Earth structure and global tectonics
- rock forming processes
- rock deformation
- past life and past climates
- Earth materials and natural resources.

There are five themes which develop and apply the knowledge and understanding of the core content. These are:

- geohazards
- geological map applications
- Quaternary geology
- geological evolution of Britain
- geology of the lithosphere.

Learners following this specification are introduced to Key Ideas which provide a framework for study.

This specification encourages learners to:

- develop essential knowledge and understanding of different areas of geology and how they relate to each other, to include civil engineering, engineering geology, hydrogeology, mining geology and petroleum geology

- develop through critical practice the skills, knowledge and understanding of scientific methods as applied in geology through a practical endorsement

- develop competence and confidence in selecting, using and evaluating a range of quantitative and qualitative skills and approaches, (including observing, collecting and analysing geo-located field data, and investigative, mathematical and problem solving skills) and applying them as an integral part of their geological studies

- understand how society makes decisions about geological issues and how geology contributes to the success of the economy and society.

This specification contains both core and non-core content as specified by the Department for Education (DfE) GCE A level subject content for geology. The purpose of the non-core content is for learners to:

- develop and apply their core knowledge and understanding
- use their core and non-core knowledge and understanding synoptically
- enrich their understanding of core concepts through an exploration of the chosen non-core areas
- be introduced to the wider context of geoscience in preparation for progression to higher education
- be exposed to current areas of research where new discoveries may revise our understanding of geological phenomena.

The WJEC Eduqas A level in Geology places problem solving at the heart of learning. Learners are encouraged to respond to geological information in both familiar and novel situations in the laboratory and in the field. Learners should be able to apply their knowledge and understanding of the contents of this specification by exploring contexts and situations that are not explicitly indicated in the specification, reflecting the skills demanded by those engaged in the study of geology, and other disciplines, beyond A level.

The specification lends itself to a variety of teaching and learning styles and offers learners of all abilities an enjoyable and positive learning experience. Practical work within the specification is vitally important in developing a conceptual understanding of many topics and it enhances the experience and enjoyment of geology.

1.2 Prior learning and progression

Any requirements set for entry to a course following this specification are at the discretion of centres. It is reasonable to assume that many learners will have achieved qualifications equivalent to Level 2 at KS4. Skills in Numeracy/Mathematics, Literacy/English and Information Communication Technology will provide a good basis for progression to this Level 3 qualification.

This specification builds on the knowledge, understanding and skills established at GCSE. Some learners may have already gained knowledge, understanding and skills through their study of geology at AS.

This specification provides a suitable foundation for the study of geology or a related area through a range of higher education courses. It also provides a good basis for many vocations, not just geological, which require initiative in thought and problem solving. In addition, the specification provides a coherent, satisfying and worthwhile course of study for learners who do not progress to further study in this subject.

This specification is not age specific and, as such, provides opportunities for learners to extend their life-long learning.

1.3 Equality and fair access

This specification may be followed by any learner, irrespective of gender, ethnic, religious or cultural background. It has been designed to avoid, where possible, features that could, without justification, make it more difficult for a learner to achieve because they have a particular protected characteristic.

The protected characteristics under the Equality Act 2010 are age, disability, gender reassignment, pregnancy and maternity, race, religion or belief, sex and sexual orientation.

The specification has been discussed with groups who represent the interests of a diverse range of learners, and the specification will be kept under review.

Reasonable adjustments are made for certain learners in order to enable them to access the assessments (e.g. candidates are allowed access to a Sign Language Interpreter, using British Sign Language). Information on reasonable adjustments is found in the following document from the Joint Council for Qualifications (JCQ): *Access Arrangements and Reasonable Adjustments: General and Vocational Qualifications.*

This document is available on the JCQ website (www.jcq.org.uk). As a consequence of provision for reasonable adjustments, very few learners will have a complete barrier to any part of the assessment.

2 SUBJECT CONTENT

Integrated Study

The WJEC Eduqas A level in Geology promotes the integrated study of geology. It enables learners to develop a broad range of skills and techniques in the areas of analysis and interpretation of data, problem-solving and drawing conclusions. In addition it enables learners to acquire data collection and interpretation skills in the field.

This specification provides knowledge of the main aspects of geology as a science through three overarching concepts which link all topics studied:

- a scientific understanding of the Earth, its evolution and its sustainable development
- the central paradigms in geology: uniformitarianism ("the present is the key to the past"); the extent of geological time; and plate tectonics
- the cycling of matter and the flows of energy into, between and within the solid Earth, the Earth's surface, the hydrosphere, the atmosphere and the biosphere.

Fieldwork

Fieldwork has long been an attractive aspect of the study of geology and has been incorporated at the heart of this specification. Learners are required to undertake a minimum of **four** days of work in the field in order to develop field observation and practical skills.

Each centre must provide a **fieldwork statement** to WJEC that details the fieldwork carried out by learners from the centre in each assessment cycle. Centres will be able to make their fieldwork statement by completing the form that will be available to download from the AS/A level Geology subject page of the Eduqas website. The fieldwork statement must be submitted to WJEC by 15 May of the year of the award.

Centres will be able to use the form to:

- confirm that each learner has been provided with opportunities to undertake geological fieldwork on **at least four occasions** and in respect of each of those opportunities:
  - the date on which it was provided
  - the number of learners who participated
  - the location at which it was provided
  - a brief description of the fieldwork undertaken
- confirm that each learner has been provided with the opportunity to undertake the compulsory fieldwork skills and techniques indicated in Appendix A, part 3.

It is recommended that centres adopt an investigative approach to fieldwork involving learners answering geological questions during their field days. Examples of suitable geological questions include:

- What does the evidence from these localities reveal about the relative time sequence of geological events in this area?

- What do the sedimentological evidence and palaeontological evidence indicate about the changes in the environments of deposition of the sedimentary rocks at this locality?
- What does the evidence of rock deformation reveal about the tectonic history of this area?

These examples are by no means the only geological questions that could be asked and centres should feel able to devise other examples of geological questions relevant to the field locations which are used. Centres must ensure that learners have been given the opportunity to complete all of the specified practical activities, including those involving fieldwork, listed in Appendix B.

Safety is paramount in the field and it is essential that all centres adhere to 'The Geological Code of Conduct' and the regulations of their centre concerning off-site activities.

This specification requires learners to:

- undertake fieldwork in different contexts: virtual fieldwork, local fieldwork outside the classroom and fieldwork on unfamiliar outcrop geology
- experience and develop competency in the skills and techniques contained in Appendix A
- apply knowledge and concepts to identify and understand field observations
- be given opportunities to develop increasing independence in their application of the investigative and practical skills and techniques in Appendix A over the A level course through progression from scaffolded to unscaffolded tasks and from familiar contexts to unfamiliar outcrop geology.

Practical work

Practical work is an intrinsic part of this specification. The practical skills developed are also fundamentally important to learners going on to further study in geology and related subjects, and are transferable to many careers.

Learners who follow this specification will develop a wide range of mathematical skills as outlined in Appendix C. Calculators may be used in all components. Candidates are responsible for making sure that their calculators meet the relevant regulations for use in written examinations: information is found in the JCQ publications *Instructions for conducting examinations* and *Information for candidates for written examinations*.

The column featuring geological techniques and skills of the subject content includes activities that must be undertaken by learners in order to ensure that they are suitably prepared for the written examinations. Items labelled SP in the column headed 'Geological techniques and skills' of the subject content, represent specified practical activities to fulfil the practical endorsement (see Appendix B).

Learners must complete the specified practical activities listed in Appendix B, which will develop the practical skills listed in Appendix A, in order to meet the requirements of the practical endorsement. These requirements are detailed in Section 3.2.

For each assessment series each centre is required to submit the Annual Head of Centre Declaration to confirm that all reasonable steps have been or will be taken to provide all candidates with the opportunity to undertake the prescribed practical activities for A Level Sciences designed for use in England.

Scientific skills

All content in the specification should be introduced in such a way that it develops learners' ability to apply the following scientific skills:

- use theories, models and ideas to develop geological explanations
- use knowledge and understanding to pose scientific questions, define geological problems, present scientific arguments and geological ideas
- use appropriate methodology, including information and communication technology (ICT), to answer geological questions and solve geological problems
- carry out fieldwork, experimental and investigative activities in a range of contexts to include the collection, compilation and analysis of Earth science data from the field and subsurface, and appropriate risk management
- manipulate and extrapolate these sometimes incomplete data sets in both two and three-dimensions
- evaluate methodology, evidence and partial data sets, and resolve conflicting evidence
- communicate information and ideas in appropriate ways (including geological maps and cross-sections) using appropriate terminology, SI units and their prefixes and the ability to express in standard form
- know that scientific knowledge and understanding develops over time, consider applications and implications of science in geology, and evaluate their associated benefits and risks
- evaluate the role of geology within the scientific community in validating new knowledge and ensuring integrity.

Areas of the specification which exemplify the scientific skills are shown in Appendix D.

Summary of content

This specification covers all the requirements of A level Geology as specified by the DfE. The knowledge, understanding, skills and techniques are set out in the two columns in the pages that follow. Learners should expect to be assessed on the details of both columns and also to answer questions that set the content in novel situations not explicit in the specification.

The specification is structured in three sections:

- **Fundamentals of Geology**
  - F1 Elements, minerals and rocks
  - F2 Surface and internal processes
  - F3 Time and change
  - F4 Earth structure and global tectonics

- **Interpreting the Geological Record**
  - G1 Rock forming processes
  - G2 Rock deformation
  - G3 Past life and past climates
  - G4 Earth materials and natural resources

- **Geological Themes**
  - T1 Geohazards
  - T2 Geological map applications
  - T3 Quaternary geology*
  - T4 Geological evolution of Britain*
  - T5 Geology of the lithosphere*

Learners study one of the options T3, T4 and T5, indicated with an asterisk.

Items labelled SP in the column headed 'Geological techniques and skills' of the subject content, represent specified practical activities to fulfil the practical endorsement (see Appendix B).

Items in italics in the geological techniques and skills column represent opportunities for the development of required mathematical skills (see Appendix C which lists the mathematical requirements with exemplification in the context of A level Geology).

This A level specification is designed to be co-teachable with the specification for the WJEC Eduqas AS in Geology. The content within the Fundamentals of Geology section forms the entire content required in the AS specification, with the exception of some additional exemplification of mathematical skills required at A level but not at AS.

Details of the components

The subject content for A level Geology is assessed across three components. The context in which the content is assessed across the three components differs.

Component 1: Geological Investigations

Written examination: 2 hours 15 minutes
35% of the qualification
105 marks

Questions in Component 1 are based on knowledge and understanding outlined in the sections Fundamentals of Geology and Interpreting the Geological Record.

Section A: Two stimulus response questions requiring short and structured answers.

Section B: A practical investigation confined to the geology of an area on a simplified geological map given on a resource sheet. The component involves the interpretation of hand specimens (sent to centres by WJEC) and photographs of minerals, rocks and fossils. In addition this assessment includes the interpretation of the simplified geological map and the construction of a geological cross-section.

A mineral data sheet accompanies Component 1. Learners should become familiar with the use of this during their study of A level Geology.

Component 2: Geological Principles and Processes

Written examination: 1 hour 45 minutes
30% of the qualification
90 marks

Questions in Component 2 are based on knowledge and understanding outlined in the sections Fundamentals of Geology and Interpreting the Geological Record.

This component involves questions which require learners to respond to aspects of geology shown in photographs, maps, diagrams and graphs. Learners are required to complete compulsory data and stimulus response questions using short, structured and extended answers.

Component 3: Geological Applications

Written examination: 2 hours
35% of the qualification
105 marks

Section A: Geohazards: Two stimulus response questions requiring short and structured answers. Questions are based on knowledge and understanding outlined in topic T1 within the section Geological Themes in addition to an understanding of the content within Fundamentals of Geology and Interpreting the Geological Record.

Section B: Geological map applications. An investigation of the geology of an area shown on a Geological Survey map extract, using stimulus response questions requiring short, structured and extended answers. Questions are based on content from the topics T1 and T2 within the section Geological Themes in addition to an understanding of the content within Fundamentals of Geology and Interpreting the Geological Record.

Section C: Learners answer questions on **one** option from a choice of three:

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

Each option comprises three questions requiring short, structured and extended answers. Questions are based on content from the relevant option topic T3, T4 or T5 within the section Geological Themes, and also require an understanding of the content within Fundamentals of Geology and Interpreting the Geological Record.

FUNDAMENTALS OF GEOLOGY

This section comprises **four** compulsory topics

F1 Elements, minerals and rocks
F2 Surface and internal processes of the rock cycle
F3 Time and change
F4 Earth structure and global tectonics

Topic F1: **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**
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).	
b. The bulk composition of the Earth is comparable with that of undifferentiated meteorites (chondrites).	
c. The Earth's crust is composed of eight main elements.	Recognition of the relative abundance of O, Si, Al, Fe, Ca, Na, K and Mg in the crust and the role of the silicates as rock-forming minerals.
d. Silicates are the commonest rock-forming minerals and are built from silicon-oxygen tetrahedra (single, chain, sheet and framework silicates).	Simple analysis of silicate mineral structures from models and diagrams.

<table>
<tr><th>Knowledge and understanding</th><th>Geological techniques and skills</th></tr>
<tr><td>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.</td><td>SP1: Investigation of diagnostic properties of minerals: colour, crystal shape, cleavage, fracture, hardness, relative density, streak, lustre, reaction with cold dilute (0.5 mol dm^{-3}) hydrochloric acid.

SP2: Measurement of the density of minerals.

Recognition, using appropriate tests, of the following rock-forming minerals (as specified on the mineral data sheet available for use in the examination) from their diagnostic properties: quartz, calcite, feldspars (orthoclase, plagioclase), augite, hornblende, olivine, micas (biotite, muscovite), haematite, galena, pyrite, chalcopyrite, fluorite, barite, halite, gypsum, garnet, chiastolite/andalusite.

SP3: Application of classification systems using distinguishing characteristics to identify unknown minerals.</td></tr>
<tr><td>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.</td><td>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/crystalline banding) and hence
• deduce the mode of origin of the rock as igneous, metamorphic or sedimentary.

SP4: 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

$$\textit{magnification} = \frac{\textit{size of image}}{\textit{size of real object}}$$</td></tr>
</table>

<table>
<tr><th colspan="2">Topic F2: SURFACE AND INTERNAL PROCESSES OF THE ROCK CYCLE</th></tr>
<tr><th colspan="2">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</th></tr>
<tr><th>Knowledge and understanding</th><th>Geological techniques and skills</th></tr>
<tr><td>a. External energy: solar heating of the Earth's surface drives the water cycle and influences weathering and erosional processes.</td><td></td></tr>
<tr><td>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.</td><td></td></tr>
<tr><td>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.</td><td>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.

Selection and use of a statistical test.</td></tr>
<tr><td>d. Different sedimentary environments may be identified by diagnostic sedimentary structures, rock textures, mineralogy and fossil content.</td><td>Description of sedimentary rocks in hand specimen, rock exposures and diagrams/photographs from observation of their colour, texture (use of sediment comparators to determine grain size, shape and sphericity), (coarse >2 mm, fine <1/16 mm), reaction with 0.5 mol dm^{-3} hydrochloric acid, mineralogy and other diagnostic features.</td></tr>
</table>

Knowledge and understanding	Geological techniques and skills
e. A study of fluvial, marine, and aeolian sediments demonstrates these differences.	Investigation of textures of sediments from different depositional environments. SP5: Production of full rock description of macro and micro features from hand specimens and unfamiliar field exposures of sedimentary rocks in order to interpret component composition, colour and textures, to identify rock types and to deduce their environment of deposition. SP6: Construction of graphic logs using appropriate scale and symbol sets for unfamiliar geological sequences and exposures to record data relevant to an investigation. SP7: Use of photomicrographs to identify minerals and rock textures of sedimentary rocks in order to identify rock types and to deduce their environment of deposition. Interpretation of maps, **photograph**s 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). 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. *Use of logarithms in relation to quantities that range over several orders of magnitude.* *Construction and interpretation of frequency tables and diagrams, bar charts and histograms.* *Knowledge of the characteristics of normal and skewed distribution*. *Plotting of variables from experimental or other circular data.* *Understanding of the terms mean, median and mode.* *Selection and use of a statistical test.* *Plotting of two variables from experimental or other linear data.*

Knowledge and understanding	Geological techniques and skills
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.
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.*

<table>
<tr><th colspan="2">Topic F2: SURFACE AND INTERNAL PROCESSES OF THE ROCK CYCLE</th></tr>
<tr><th colspan="2">Key Idea 2: The formation and alteration of igneous and metamorphic rocks result from the Earth's internal energy</th></tr>
<tr><th>Knowledge and understanding</th><th>Geological techniques and skills</th></tr>
<tr><td>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).</td><td>Interpretation of evidence for surface heat flow and temperature variation with depth through simple analysis of the geothermal gradient (geotherm).

Solving of algebraic equations.

Calculation of the rate of change from a graph showing a linear relationship.</td></tr>
<tr><td>b. Igneous rocks are the products of cooling of magma in bodies of various sizes and shapes and pyroclastic events.</td><td>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.

SP8: Production of full rock description of macro and micro features from hand specimens and/or unfamiliar field exposures of igneous rocks in order to interpret component composition, colour and textures, to identify rock type and to deduce their cooling history.

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.

SP9: Use of photomicrographs to identify minerals and rock textures of igneous rocks to identify rock type and to deduce their cooling history.</td></tr>
</table>

Knowledge and understanding	Geological techniques and skills
	Use of ratios, fractions and percentages. *Calculation of the circumferences, surface areas and volumes of regular shapes.* *Construction and interpretation of frequency tables and diagrams, bar charts and histogram.* *Knowledge of the characteristics of normal and skewed distributions.*
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.
e. The nature of the volcanic hazard is linked to the composition, viscosity and gas content of the magma.	
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.

Knowledge and understanding	Geological techniques and skills
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*. SP10: Production of full rock description of macro and micro features from hand specimens and/or unfamiliar field exposures of metamorphic rocks in order to interpret component composition, colour and textures, to identify rock type and to deduce the temperature and pressure conditions of their formation. SP11: Use of photomicrographs to identify minerals and rock textures of metamorphic rocks to identify rock type and to deduce the temperature and pressure conditions of their formation. 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.

Topic F2: **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**
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.	
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). *Use of sin, cos and tan in physical problems.* Recognition and interpretation of structural features through study of photographs, diagrams, sections, geological maps and in the field. SP12: Location of geological features onto a base map. SP13: Identification of the location of geological features in the field using six figure grid references on maps. SP14: Production of scaled, annotated field sketches at unfamiliar field exposures to record data relevant to an investigation. SP15: Measurement of dip and strike elements: dip angle, dip and strike directions of planar surfaces, including valid sampling, relevant to an investigation.
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.

Knowledge and understanding	Geological techniques and skills
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).
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.
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.

<table>
<tr><th colspan="2">Topic F3: TIME AND CHANGE</th></tr>
<tr><th colspan="2">Key Idea 1: Study of present day processes and organisms enables understanding of changes in the geological past</th></tr>
<tr><th>Knowledge and understanding</th><th>Geological techniques and skills</th></tr>
<tr><td>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.

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.</td><td>Investigation of the development of uniformitarianism and the rock cycle model over time and the contributions of James Hutton and William Smith.</td></tr>
<tr><td>d. Fossils are evidence of former life preserved in rocks. They provide information on the nature of ancient organisms and palaeoenvironmental conditions.</td><td>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).

SP16: Application of classification systems using distinguishing characteristics to identify unknown fossils.

SP17: Production of scaled, annotated scientific drawings of fossils, using a light microscope, or hand lens observation.</td></tr>
</table>

Knowledge and understanding	Geological techniques and skills
e. Fossil morphology is used to interpret function/mode of life: • bivalves (burrowers/non burrowers) • trilobites (benthonic/pelagic).	
f. Preservation can give rise to a wide range of fossil materials: actual remains, hard parts, petrification by mineral replacement (calcification, silicification, pyritisation), carbonisation, moulds/casts.	
g. Fossils accumulations may be preserved without appreciable transportation (life assemblages) or preserved after transportation (death assemblages), or as derived fossils re-deposited in later sediment.	Analysis of modern and fossil assemblages to interpret the degree of transportation prior to burial.
h. The fossil record is: • biased, in favour of marine organisms, with body parts resistant to decay, that lived in low energy environments, and suffered rapid burial • incomplete, as natural processes can distort or destroy fossil evidence (predation, scavenging, diagenesis, bacterial decay, weathering, erosion, metamorphism)	

Topic F3: **TIME AND CHANGE**	
Key Idea 2: **Geological events can be placed in relative and absolute time scales**	
Knowledge and understanding	**Geological techniques and skills**
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.
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.
c. Fossils are used in relative dating.	Observation and identification of appropriate morphological features and their changes through time: • **graptolites** - number and position of stipes, thecal shape in the Early Palaeozoic. • **cephalopods -** suture lines in the Late Palaeozoic and Mesozoic (goniatite, ceratite and ammonite).
d. The factors contributing to good zone fossils for relative dating/correlation are: wide and plentiful distribution, ready preservation, rapid evolutionary change, a high degree of facies independence, easy identification of index fossils. • the utility of graptolites and cephalopods as zone fossils assessed in relation to the above factors.	
e. The geological column provides a means of: • placing geological events in their correct time sequence • defining the absolute age of some events.	Interpretation of the ages of geological events using the geological column.
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 F4: **EARTH STRUCTURE AND GLOBAL TECTONICS**	
Key Idea 1: **The Earth has a concentrically zoned structure and composition**	
Knowledge and understanding	**Geological techniques and skills**
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.* SP18: Measurement of the densities of representative samples of Earth layers (e.g. granite, basalt). Simple analysis of geomagnetic evidence for core composition and processes.
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).

<table>
<tr><th colspan="2">Topic F4: EARTH STRUCTURE AND GLOBAL TECTONICS</th></tr>
<tr><th colspan="2">Key Idea 2: The Earth's internal heat is the underlying cause of lithospheric plate motions that control global geological processes</th></tr>
<tr><th>Knowledge and understanding</th><th>Geological techniques and skills</th></tr>
<tr><td>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).</td><td>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).</td></tr>
<tr><td>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.</td><td>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).

SP19: Investigation of the relationships between earthquake data (focal depth, magnitude and distance from plate boundaries) using data on Google Earth™.

Use of a scatter diagram to identify a correlation between two variables.</td></tr>
<tr><td>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.</td><td>Evaluation of the possible mechanisms for plate movement (role of mantle convection, slab pull, ridge push).</td></tr>
</table>

Knowledge and understanding	Geological techniques and skills
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. 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.	

INTERPRETING THE GEOLOGICAL RECORD

This section comprises **four** compulsory topics

G1 Rock forming processes
G2 Rock deformation
G3 Past life and past climates
G4 Earth materials and natural resources

Topic G1 : **ROCK FORMING PROCESSES**	
Key Idea 1: **The generation and evolution of magma involves different processes**	
Knowledge and understanding	**Geological techniques and skills**
a. Igneous rock composition at interplate and intraplate settings depends on: • origin of the parent magma (mantle or crust) • magma evolution: Differentiation and fractionation (continuous and discontinuous reaction series - Bowen); gravity settling to give cumulates • magma contamination: incorporation of rock material (xenoliths); magma mixing, during rise and emplacement, leading to change of composition and physical properties (enclaves).	Evaluation of the role of temperature, pressure and water content in determining the melting points of rocks. Simple calculation of depth of formation of granite magma by crustal melting through interpretation of graphs showing continental geotherm and melting temperatures of wet and dry lower crustal material. Calculation of the age of a mineral sample using the decay rate equation $N = N_0e^{-\lambda t}$ *Use of logarithms in relation to quantities that range over several orders of magnitude.* *Interpretation of logarithmic plots.* *Calculation of percentage error in radiometric dating results.*
b. The substitution of one element for another in the crystal structure of a mineral depends upon atomic radius and valency; solid solution as exemplified by olivine and plagioclase feldspar.	Investigation of magma crystallisation and differentiation processes using phase diagrams (plagioclase feldspar, olivine).
c. The formation of magma chambers under ocean ridges and rises can be interpreted from models.	Analysis of ocean survey data to investigate current models of how oceanic ridges (particularly mid ocean ridges - MORs) are formed (e.g. RRS James Cook -2016).

Topic G1 : **ROCK FORMING PROCESSES**	
Key Idea 2: **The mineralogy and texture of metamorphic rocks are determined by the composition of the parent rock and the conditions of metamorphism**	
Knowledge and understanding	**Geological techniques and skills**
a. Igneous and sedimentary rocks contain minerals that are stable or metastable at the temperature and pressure of their formation. Changes in temperature and/or directed stress over time lead to the growth of new minerals with different stability fields.	Analysis of simple pressure - temperature - time paths involved in contact and regional metamorphism. Simple analysis of phase diagrams showing stability fields of selected metamorphic minerals: kyanite/ sillimanite/andalusite.
b. Mineralogical changes during metamorphism depend on the composition of the parent rock and the temperature/pressure field.	SP20: Investigation of contact metamorphism using the 'Metamorphic Aureole' simulation experiment.
c. Contact and regional metamorphism of mudstone/shale lead to the growth of new minerals indicative of the type and grade of metamorphism: low to high grade metamorphism.	
d. Contact, regional and dynamic metamorphism result from different pressure/temperature conditions and produce characteristic textural changes associated with recrystallization, ductile flow and shear deformation.	Study of diagrams/photomicrographs to identify and analyse the following metamorphic textures: granoblastic; porphyroblastic; mylonitic.

Topic G1: **ROCK FORMING PROCESSES**	
Key Idea 3: **Sedimentary processes can be understood using scientific modelling**	
Knowledge and understanding	**Geological techniques and skills**
a. Sedimentary processes which are infrequent and/or difficult to observe (e.g. turbidity currents) can be understood and explained using scientific models.	Application of the Hjulstrom graph. *Determination of the slope and intercept of a linear graph.*
b. The distribution of environments represented by rocks in a vertical stratigraphic column is related to the distribution of those environments laterally (Walther's Law); marine transgressions and regressions, diachronous stratigraphic boundaries.	Application of Walther's Law to extend interpretation from two-dimensional data (borehole logs, cliff sections, graphic logs) to three-dimensions.

Topic G2: **ROCK DEFORMATION**	
Key Idea 1: **Geological structures are formed when rock material undergoes deformation**	
Knowledge and understanding	**Geological techniques and skills**
a. The nature of rock deformation is determined by the competence of the parent rock and conditions during deformation (temperature, confining pressure, strain rate).	Recognition of the differences in deformation of competent and incompetent rocks.
b. Fold characteristics; amplitude, wavelength, interlimb angle (open, tight, isoclinal), axial plane attitude (upright, inclined, overturned, recumbent), plunging folds.	Identification of plunge direction (of axis) and axial planar cleavage. *Represent limb dip and strike data on a polar equal area stereonet (polar plots only not projections or great circles).* *Plotting of variables from experimental or other circular data.*
c. Fault type is determined by the orientation of the principal stresses. Technical terms to describe fault elements: slickensides, fault gouge, fault breccia.	Analysis of the relationship between fault type (normal, reverse/thrust, strike-slip) and the orientation of the principal stress components (σ max, σ int, σ min).
d. Structural reactivation: earlier-formed faults can be reactivated during later tectonism; folds may be refolded. Structural inversion: reactivation of normal faults in compression or reverse faults/thrusts in extension.	Recognition of evidence for fault reactivation on geological maps, cross-sections, diagrams and photographs.
e. The nature of outcrop patterns formed by the intersection of geological structures with a topographic surface are displayed on geological maps.	Calculations involving measurements of: • true bed thickness • vertical bed thickness • width of outcrop • angle of dip. *Use of sin, cos and tan in physical problems.*

<table>
<tr><th colspan="2">Topic G3: PAST LIFE AND PAST CLIMATES</th></tr>
<tr><th colspan="2">Key Idea 1: Fossils provide evidence for the increasing diversity of life through geological time</th></tr>
<tr><th>Knowledge and understanding</th><th>Geological techniques and skills</th></tr>
<tr><td>a. The fossil record provides evidence of changes in floras and faunas through geological time and the development of higher life forms:
• Precambrian life: life possibly evolved early in Earth history (3.8 billion years ago). The Ediacaran fauna represents the oldest diverse set of multicellular, soft bodied organisms (565 Ma)
• The Cambrian Explosion: the development of mineralised skeletons led to a wide variety of advanced marine invertebrates by the early Cambrian
• Life in the ocean diversified in stages identified by separate fauna: a basic understanding of the difference between Cambrian, Palaeozoic and modern faunas
• The Phanerozoic was marked by the migration of organisms onto the land during the Palaeozoic. Vertebrate development of amphibians from fish, reptiles from amphibians and mammals and birds from reptiles. Colonisation by of the land by plants.</td><td>Interpretation of evolutionary diagrams.

Analysis of the possible causes of faunal diversification at the Precambrian-Cambrian boundary.

Interpretation of simple diversity curves (Sepkoski’s curves).

Analysis of the morphology of fossil vertebrates (including dinosaurs) to interpret function/mode of life.</td></tr>
<tr><td>b. Diversity increased through the Phanerozoic punctuated by many declines caused by mass extinction events. Mass extinctions may result from a variety of causes including:
• asteroid impact (Alvarez)
• large scale volcanicity (flood basalts)
• changes in land/sea levels
• rapid climate change.

c. Mass extinctions are exemplified by the end-Permian (P-T) and Cretaceous-Paleogene (K-Pg) boundary events.</td><td>Evaluation of contrasting hypotheses regarding mass extinctions.</td></tr>
<tr><td>d. There are alternative interpretations of evolutionary patterns based on the fossil record. Gradual change (gradualism) vs stability interrupted by sudden change (punctuated equilibrium).</td><td>Evaluation of alternative interpretations of evolutionary patterns.</td></tr>
</table>

Topic G3: **PAST LIFE AND PAST CLIMATES**	
Key Idea 2: **A combination of global factors contributes to climate change through geological time**	
Knowledge and understanding	**Geological techniques and skills**
a. Long-term changes to the global climate, composition of the atmosphere, sea level and distribution of the continents are recorded in the Phanerozoic rock record. The J. Tuzo Wilson Cycle provides a framework for understanding these long term changes.	Analysis of *present day* oceanic and atmospheric circulation in relation to climatic effects. Analysis of data used to determine *past* climatic regimes.
b. Changes in the atmospheric composition of greenhouse gases (especially CO_2 and methane) result from natural processes (volcanic activity, rock weathering, warming of methane hydrates) throughout geological time.	Evaluation of the contribution of naturally produced CO_2 and methane to climate change with time.
c. There have been climate changes throughout geological time. The current rate of change appears to differ from those in the past.	Analyses of graphs showing different rates of climate change.
d. The Anthropocene is a proposed epoch that began when human activities changed the Earth's surface environment on a scale comparable with the major events of the geological past. There is currently a lack of consensus for the proposed epoch.	Evaluation of the arguments in the debate for the inclusion of the Anthropocene as a new epoch.

Topic G3: **PAST LIFE AND PAST CLIMATES**	
Key Idea 3: **Evidence for global climate change is interpreted from the geological record and the geochemistry of rocks**	
Knowledge and understanding	**Geological techniques and skills**
a. Evidence for global climate changes can be interpreted from both the geological record and the isotope geochemistry of ocean-floor sediments.	Investigation of the evidence for climatic extremes in the rock record.
b. The fossil record provides evidence of different climatic zones, as exemplified by: • land plants • corals.	
c. Sedimentary sequences provide evidence of palaeoenvironments related to particular climatic zones. • Ancient icehouse deposits (e.g Carboniferous). • Tropical greenhouse deposits (e.g. Cretaceous).	
d. Oxygen isotope ratios ($^{18}O/^{16}O$) in fossil shells are indicative of the temperature of ancient ocean waters.	Simple analysis of oxygen isotope curves.
e. The “Snowball Earth” hypothesis proposes that the Earth's surface became entirely or nearly entirely frozen at least once, sometime earlier than 650 Ma.	Assessment of the validity of the evidence for the “Snowball Earth” hypothesis in Neoproterozoic rocks.

Topic G4 : **EARTH MATERIALS AND NATURAL RESOURCES**	
Key Idea1: **Geological processes lead to the concentration and accumulation of natural resources in deposits that can be exploited; economic deposits can be concentrated by igneous and sedimentary processes**	
Knowledge and understanding	**Geological techniques and skills**
a. Processes of formation of metalliferous ores. • Igneous associations of ores - magmatic segregation, hydrothermal activity. • Sedimentary associations of ores - placer deposits; residual deposits; precipitated deposits.	Geological map interpretation (ore body geometry, field relations); section-drawing through ore bodies. *Calculation of the circumferences, surface areas and volumes of regular shapes.* *Recognition and making use of appropriate units in calculations.* *Use of ratios, fractions and percentages.* Geological map interpretation; section drawing through industrial mineral deposits.
b. Processes of formation of non-metallic minerals of economic importance: china clay. c. Formation of sedimentary deposits of economic importance as "bulk minerals" for aggregate: sand and gravel.	
d. Origin of hydrocarbons and coals: hydrocarbons and coals result from the thermal alteration of organic material due to burial. • Hydrocarbons: source rocks; sediment burial and the temperature and pressure conditions of oil and natural gas formation. • Coal-forming environments; peat, lignite, bituminous coal, anthracite; coal rank.	Simple analysis of maturity: depth (temperature) graphs showing oil and natural gas windows. Identification of coal types. Simple assessment of reserves (e.g. tonnage of coal in a given area). *Calculation of the circumferences, surface areas and volumes of regular shapes.*

Topic G4 : **EARTH MATERIALS AND NATURAL RESOURCES**	
Key Idea 2: **Permeable rocks offer pathways for oil and gas migration; highly porous rocks can act as natural reservoirs for underground supplies of oil and gas**	
Knowledge and understanding	**Geological techniques and skills**
a. Porosity and permeability of rock and sediments affects the presence, distribution and migration of fluids (water oil and natural gas): primary/secondary porosity in rock; factors that affect porosity and permeability.	Analysis of rock textures in terms of porosity and permeability (grain size, shape, packing, sorting; cementation); primary and secondary porosity.
b. Fluid flows in rocks and sediment can be modelled using Darcy's Law.	Application of Darcy's Law to model fluid flow: $Q = -kA\left(\frac{h_2 - h_1}{L}\right)$
c. Oil and gas migration are controlled by geological factors: migration paths - relative buoyancy of oil and natural gas; structural and stratigraphic traps for hydrocarbons; reservoir rocks and cap rocks.	Analysis of geological cross-sections through oil and natural gas bearing structures.
d. The characteristics of subsurface geology which control the flow of groundwater (hydrogeology) include confined and unconfined aquifers, aquicludes, aquitards, the water table, piezometric surfaces, cones of depression and recharge zones.	Analysis of the controls on groundwater quality which result from geochemistry (carbonates and sulfates), aquifer filtration, residence time and sources of pollution.

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

GEOLOGICAL THEMES

This section comprises **two** compulsory topics

T1 Geohazards

T2 Geological map applications

and **one** option topic from

T3 Quaternary geology

T4 Geological evolution of Britain

T5 Geology of the lithosphere

Topic T1 : **GEOHAZARDS**	
Key Idea 1: **Natural geohazards have a worldwide impact on human populations including in the British Isles**	
Knowledge and understanding	**Geological techniques and skills**
a. Seismic hazards. • There is a relationship between earthquakes and active fault zones. • The magnitude of an earthquake event is measured on the Moment Magnitude scale **(**M_W**).** The intensity of earthquake damage around an event is measured on the modified Mercalli scale and is related to earthquake size, depth, distance, local ground conditions and building standards. • Seismic hazards include ground shaking, liquefaction. • Tsunamis can cause devastation in coastal areas following an undersea earthquake (landslide or volcanic eruption).	Analysis of geological data from appropriate case studies of each the following: • a major earthquake • a mass movement event to compare and contrast the nature of the geological hazards. Investigation of the factors that affect the impact of earthquakes and mass movements
b. Mass movement hazards. • The mechanism and triggering of rock avalanches, landslides and debris flows are linked to angle of slope, lithology, weathering, load, groundwater regime, rainfall, ground vibration, vegetation cover.	
c. The British Isles is prone to local natural geohazards at different scales associated with: earthquakes, landslides, shrinking and swelling clays and subsidence (including sink holes).	Analysis of the causes and effects of geohazards in the British Isles from appropriate data sets.
d. There is evidence that significant tsunamis have affected the British coast in the recent geological past.	

Topic T1 : **GEOHAZARDS**	
Key Idea 2: **Geohazard management attempts to predict and manage hazardous geological events with only limited success**	
Knowledge and understanding	**Geological techniques and skills**
a. Geohazard and risk are intimately linked. • Geohazard: the probability of a change in the geological environment of a given magnitude within a specific time period in a given area. • Risk: the consequent threat of loss of life or damage to property and infrastructure. b. The risk assessment of geohazards involves an analysis of: • the nature of the hazard • the probability of occurrence and the return period of the hazard • communication of the risk to the vulnerable population. c. Attempts to predict earthquakes include monitoring changes in: seismic activity, groundwater levels and pressure, ground deformation (creep meters, strain meters, tilt meters), radon gas emissions and electrical resistivity. d. Sites of potential slope failure can be monitored by: • ground levelling and surveying; monitoring of micro-seismic events and borehole distortion; ground deformation (creep, strain, tilt) and groundwater pressures • Use of electronic distance measurement (EDM), satellite and GPS techniques. e. The destructive effects of earthquakes and mass movements can, to some extent, be managed and controlled by engineering geology applications. • Earthquakes: reducing of the impact of ground accelerations; aseismic building design; tsunamis defences. • Mass movement: slope stabilisation methods, drainage control, retaining structures.	*Understanding of simple probability.* An investigation of the monitoring of: • a major earthquake • a mass movement event evaluating the level of success in hazard prediction.

<table>
<tr><th colspan="2">Topic T1 : GEOHAZARDS</th></tr>
<tr><th colspan="2">Key Idea 3: Engineering activities can have a major impact on the natural environment</th></tr>
<tr><th>Knowledge and understanding</th><th>Geological techniques and skills</th></tr>
<tr><td>a. Extraction of geological raw materials and economic storage of waste products involves interference with the surface and/or subsurface environment.
• Quarrying and mining. Problems associated with the extraction of rock and minerals – stability of working faces, rock falls, ground subsidence, flooding, surface/groundwater pollution and waste tipping.</td><td>Analysis of the methods of extraction of geological raw materials to identify potential environmental problems and the ways by which these may be minimised.</td></tr>
<tr><td>• Waste disposal. Problems of ground contamination, including groundwater pollution and methane gas production, can be ameliorated by good geological site selection and engineering practice. There are special problems with the disposal of highly toxic chemical and radioactive waste.</td><td>Analysis of landfill engineering data for the disposal of domestic waste or underground sites for the disposal of highly toxic chemical and radioactive waste.</td></tr>
<tr><td>• Contaminated land. Problems with the management and remediation of industrial brownfield sites associated with toxic chemical materials, ground instability, subsidence and groundwater pollution.</td><td>Analysis of the issues associated with the remediation of one industrial brownfield site.</td></tr>
<tr><td>b. Civil engineering work should take account of geological factors to avoid:
• problems of ground instability associated with weathering, dip of strata, folding, faulting, rock cleavage, joint patterns and fracture density
• interference with the hydrological system: pore water pressure, surface and underground drainage (porosity, permeability, water table, aquifers)
• radon gas - sources and pathways to surface, surface geology of high-risk areas.</td><td>Simple analysis of rock slope stability involving friction angle and orientation of rock discontinuities.

Analysis of the suitability of sites using a variety of geological and geotechnical data.</td></tr>
<tr><td>c. In building major structures geological factors and geological rock properties must be taken into account (e.g. dams and reservoirs, cuttings and tunnels, buildings).</td><td></td></tr>
</table>

Topic T2 : **GEOLOGICAL MAP APPLICATIONS**	
Key Idea 1: **Outcrop patterns on geological maps can be used to identify and interpret structural elements**	
Knowledge and understanding	**Geological techniques and skills**
a. Outcrop patterns of dipping strata and faults in relation to topography: direction of closure of V-shaped outcrops in valleys as an indication of dip direction; close parallelism of geological boundaries and topographic contours as a sign of near horizontal dip; linear geological boundaries crossing topographic relief as an indication of steep dip.	Interpretation of relationships between structural features, outcrops and topography on geological maps. Identification of fold types using outcrop patterns on geological maps. Identification of fault types and measurement of displacements using offsets of geological boundaries across faults. Identification of unconformities based on field relationships displayed on geological maps. Analysis of the 3D nature of geological maps and cross-sections using block diagrams and/or GIS systems (including Google Earth™).

Topic T2 : **GEOLOGICAL MAP APPLICATIONS**	
Key Idea 2: **Geological maps contain information relevant to a wide range of geological applications**	
Knowledge and understanding	**Geological techniques and skills**
a. Geological maps provide an essential database of detailed information about the distribution of rocks at the surface that can be used to interpret or predict subsurface geological conditions.	Use of geological maps at various scales to identify from outcrop patterns and other data on geological maps: • conformable and unconformable sedimentary formations • metamorphic sequences and igneous bodies (and any associated metamorphic effects) • structural features.
b. Geological maps provide an essential database for geological applications:	Use of geological maps at various scales to:
• design of construction projects	assess the potential of surface sites for a range of engineering projects on the basis of the prevailing geology
• identification of geological hazards	identify geological hazards (landslides, subsidence) at defined surface sites on the basis of the prevailing geology
• location of resources - groundwater, fossil fuels; alternative energy sources	interpret subsurface geology in connection with groundwater (water table, springs, aquifers, artesian wells), coal, oil, natural gas and geothermal energy
• identification of environmental issues from extraction of these resources	identify the environmental issues specific to extraction of resources from the map area
• assessment of suitability for sustainable waste disposal or brownfield remediation.	assess the suitability for sustainable waste disposal/contaminated land remediation in a given area.

Option T3: **QUATERNARY GEOLOGY**	
Key Idea 1: **A combination of global factors contributes to climate change through geological time**	
Knowledge and understanding	**Geological techniques and skills**
a. Milankovitch cycles are regarded as a contributory cause of climatic fluctuations during the Quaternary.	
b. The distribution of continents and mountain belts affects oceanic and atmospheric circulation, influencing past and present global climate.	Analysis of present day oceanic and atmospheric circulation in relation to climatic effects.
c. The switch from a global greenhouse to icehouse climate is moderated by the efficiency of heat transfer from equatorial to polar latitudes; possible influence of the opening of the Drake Passage and rise of the Himalayan mountains.	

Option T3: **QUATERNARY GEOLOGY**	
Key Idea 2: **The wide range of Quaternary deposits and landforms provides a fragmentary record of former glacial and interglacial stages in Britain**	
Knowledge and understanding	**Geological techniques and skills**
a. The wide range of glacial, periglacial, fluvioglacial and interglacial deposits and landforms in Britain provides an incomplete record of climatic fluctuations and varying sedimentary environments. Information may be deduced on ice sheet dimensions and ice movement patterns. b. There is geological evidence for glacial and interglacial stages, and for shorter-term climatic cycles superimposed on the dominant pattern of glacial and interglacial stages.	
c. There is a link between continental ice sheets and sea level: low sea levels during glacials, high sea levels during interglacials. Isostatic response to ice loading and unloading.	Analysis of evidence for Quaternary sea level changes (e.g. raised beaches, drowned valleys). Simple calculations of amount of rebound caused by ice unloading. Analysis of evidence for relative changes in sea level caused by ice loading.
d. The fragmentary terrestrial record of climate change contrasts with a near complete oceanic record: oxygen isotope evidence ($^{18}O/^{16}O$) from ocean sediments provides evidence of climate fluctuations through the Quaternary. e. Ice core evidence for atmospheric change.	

<table>
<tr><th colspan="2">Option T3: QUATERNARY GEOLOGY</th></tr>
<tr><th colspan="2">Key Idea 3: Fossils provide evidence of environmental and climate changes in the Quaternary to which dating techniques can be applied</th></tr>
<tr><th>Knowledge and understanding</th><th>Geological techniques and skills</th></tr>
<tr><td>a. Fossils provide evidence for climatic fluctuations in Britain during the Quaternary period.

b. Environmental change and climate instability over the past six million years may have been responsible for shaping human evolution and the ability to adapt to changing conditions.

c. A variety of techniques are available to date Quaternary events including:
• Radiocarbon (^{14}C) dating (organic material)
• Incremental dating (varves, tree rings)
• Isochronous marker beds (volcanic ash layers).

Each method has particular applications and limitations.</td><td>Analysis of pollen diagrams. Analysis of the vertebrate /invertebrate record. (e.g. woolly mammoths, beetles).

Evaluation of fossil evidence for hominin evolution (up to Homo sapiens) compared to the evidence for environmental and climatic change.</td></tr>
</table>

Option T4: **GEOLOGICAL EVOLUTION OF BRITAIN**	
Key Idea 1: **The Neoproterozoic and Phanerozoic stratigraphy of the British area has been determined largely by the assembly of lithotectonic terranes during three orogenic events**	
Knowledge and understanding	**Geological techniques and skills**
a. Rocks from all the major subdivisions of geological time occur in Britain and surrounding shelf areas: Precambrian, Early and Late Palaeozoic, Mesozoic, Cenozoic.	Study of geological maps at various scales including maps linking onshore and offshore areas. Use of maps and related data to investigate major geological processes operating in different parts of the British area from the Precambrian to the Quaternary.
b. Information used to investigate the geological history of the British Isles also includes remote sensing techniques that provide an indirect way to investigate the subsurface geology. The principles associated with: • potential field measurements gravity (Bouguer anomaly) and magnetic surveys • borehole analysis; as exemplified by the Mochras Borehole. • seismic reflection surveys; onshore and offshore.	Application of remote sensing and subsurface data collection to help interpret the Palaeozoic and Neoproterozoic geology of the British area.
c. A number of orogenic events have affected the British area: location and large-scale geology. Ages, main structures and dominant trends of the Caledonian and Variscan orogenic belts; Alpine orogenic influences in Britain.	Interpretation of geological maps to identify outcrop patterns associated with large-scale geological features of orogenic belts; fold shapes and descriptors, plunging folds; fault descriptors; regional structural trends as displayed by major folds and faults.
d. Study of the geology (plutonic/volcanic and metamorphic rocks) of these orogenic belts aids the reconstruction of the plate tectonic regimes in which they developed.	Collation and evaluation of geological evidence to interpret the Caledonian and Variscan orogenic belts and Palaeogene Igneous Province in plate tectonic terms.
e. The Palaeogene Igneous Province of NW Britain provides evidence of the early history of the opening of the North Atlantic Ocean, with associated basaltic volcanicity.	Interpretation of the geological characteristics of the Palaeogene Igneous Province in plate tectonic terms.

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

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

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

Option T5: **GEOLOGY OF THE LITHOSPHERE**	
Key Idea 2: **Oceanic lithosphere is formed at divergent plate boundaries and reabsorbed by subduction at convergent plate boundaries**	
Knowledge and understanding	**Geological techniques and skills**
a. The ocean crust has a layered structure: seismic layers 1, 2 and 3.	Geological interpretation of seismic layers 1, 2 and 3 (sediments, pillow lavas, sheeted dykes and gabbro) using evidence from ophiolites and ocean drilling.
b. Ophiolites and ocean drilling provide evidence for the origin and composition of the oceanic crust and upper mantle.	Investigation of an ophiolite complex.
c. Ocean basin evolution can be traced from continental rifts through narrow seas to mature ocean basins: the J. Tuzo Wilson cycle.	Analysis of the evidence for ocean growth and destruction as a cyclic event.
d. Rates and directions of seafloor spreading may be calculated from the dating of oceanic crust and from the patterns of ocean magnetic anomalies caused by field reversals: use of radiometric dating and ocean drilling to date magnetic anomalies.	Interpretation of ocean magnetic anomaly profiles and maps and ocean floor age distribution maps; calculation of rates of seafloor spreading from magnetic anomaly and mantle plume (hotspot) data – plumes as frames of reference for absolute plate movements.

Option T5: **GEOLOGY OF THE LITHOSPHERE**	
Key Idea 3: **A wide range of lithospheric processes contributes to the formation of continental crust**	
Knowledge and understanding	**Geological techniques and skills**
a. Supercontinents have assembled and dispersed multiple times in the geologic past and takes place in cycles on a global scale: e.g. Rodinia, Pangea.	Investigation of the concept of a supercontinent and the limitation in evidence beyond 200 Ma.
b. Being of relatively low density, continental lithosphere resists subduction and tends to avoid destruction during plate tectonic cycles, hence the Earth's oldest crustal rocks are found in continental areas.	Investigation of the age distribution of rocks in continental areas using geological maps.
c. Orogenic belts are sites of major lithospheric thickening. • continent- continent collision. • continent-island arc collision. • cordilleran mountain belts. • incorporation of oceanic lithosphere into orogenic belts; ophiolites and accretionary prisms. • partial melting and granite. • magmatism; delamination. • isostatic uplift and gravitational collapse.	Identification of large scale features of continental geology and interpretation of their origin and tectonic setting. Investigation of isostasy in continental and oceanic lithosphere.
d. Forces acting on the continental crust (plate boundary forces and gravitational spreading) give rise to tectonic stresses that cause brittle and ductile deformation on all scales in crustal rocks.	Field interpretation of folds and faults in terms of applied stresses, and their relationship to the regional structural setting.
e. Regional structures. • fold and thrust belts. • nappe structures occur in compressive tectonic settings and may include large-scale recumbent folds together with shearing along low angle, thrust faults.	
f. Major sedimentary basins are controlled by lithospheric extension (extensional basins) and lithospheric loading (foreland basins).	Investigation of the origin and structural control of major sedimentary basins using maps and sections.

3 ASSESSMENT

3.1 Assessment objectives and weightings

Below are the assessment objectives for this specification. Learners must:

AO1
Demonstrate knowledge and understanding of geological ideas, skills and techniques

AO2
Apply knowledge and understanding of geological ideas, 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

The table below shows the weighting of each assessment objective for each component and for the qualification as a whole.

	AO1	AO2	AO3	Total
Component 1	6.6%	16%	12.4%	35%
Component 2	9.7%	13%	7.3%	30%
Component 3	13.7%	13%	8.3%	35%
Overall weighting	30%	42%	28%	100%

For each series:

- The weighting for the assessment of mathematical skills will be a minimum of 10%.
- The weighting for the indirect assessment of practical skills will be a minimum of 15%.

The ability to select, organise and communicate information and ideas coherently using appropriate scientific conventions and vocabulary will be tested across the assessment objectives.

3.2 Arrangements for non-exam assessment

Practical Endorsement

The assessment of practical skills is a compulsory requirement of the course of study for A level qualifications in Geology. It will appear on all learners' certificates as a separately reported result, alongside the overall grade for the qualification. The arrangements for the assessment of practical skills will include:

- 20 practical activities to be carried out by each learner which, together, meet the requirements of Appendix 1 part (b) (practical skills identified for direct assessment and developed through teaching and study) and Appendix 1 part (c) (use of apparatus and techniques) from the prescribed subject content, published by the Department for Education.

- Teachers will assess learners against Common Practical Assessment Criteria (CPAC) issued by the awarding organisations. The CPAC (see the following pages) are based on the requirements of Appendix 1 parts (b) and (c) of the subject content requirements published by the Department for Education, and define the minimum standard required for the achievement of a pass grade.

- Each learner will keep an appropriate record of their assessed practical activities.

- Learners who demonstrate the required standard across all the requirements of the CPAC will receive a 'pass' grade.

- Learners will answer questions in the A level examination papers that assess the requirements of Appendix 1 part (a) (practical skills identified for indirect assessment and developed through teaching and study) from the prescribed subject content, published by the Department for Education.

<table>
<tr><th colspan="2">Common Practical Assessment Criteria (CPAC)</th></tr>
<tr><td colspan="2">In order to be awarded a pass, a learner must, by the end of the practical geology assessment, consistently and routinely meet the criteria in respect of each competency listed below. A learner may demonstrate the competencies in any practical activity undertaken as part of that assessment throughout the course of study.

Learners may undertake practical activities in groups. However, the evidence generated by each learner must demonstrate that he or she independently meets the criteria outlined below in respect of each competency.

Such evidence:
(a) will comprise both the learner's performance during each practical activity and his or her contemporaneous record of the work that he or she has undertaken during that activity, and
(b) must include evidence of independent application of investigative approaches and methods to practical work.

Teachers who award a pass to their learners need to be confident that the learner consistently and routinely exhibits the competencies listed below before completion of the A level course.</td></tr>
<tr><td>1. Follows written procedures</td><td>Correctly follows instructions to carry out the experimental techniques or procedures.</td></tr>
<tr><td>2. Applies investigative approaches and methods when using instruments and equipment</td><td>Correctly uses appropriate instrumentation, apparatus and materials (including ICT) to carry out investigative activities, experimental techniques and procedures with minimal assistance or prompting.

Carries out techniques or procedures methodically, in sequence and in combination, identifying practical issues and making adjustments when necessary.

Identifies and controls significant quantitative variables where applicable, and plans approaches to take account of variables that cannot readily be controlled.

Selects appropriate equipment and measurement strategies in order to ensure suitably accurate results.</td></tr>
</table>

3.	Safely uses a range of practical equipment and materials	Identifies hazards and assesses risks associated with these hazards, making safety adjustments as necessary, when carrying out experimental techniques and procedures in the lab or field. Uses appropriate safety equipment and approaches to minimise risks with minimal prompting.
4.	Makes and records observations	Makes accurate observations relevant to the experimental or investigative procedure. Obtains accurate, precise and sufficient data for experimental and investigative procedures and records this methodically using appropriate units and conventions.
5.	Researches, references and reports	Uses appropriate software and/or tools to process data, carry out research and report findings. Sources of information are cited demonstrating that research has taken place, supporting planning and conclusions.

For each assessment series each centre is required to submit the Annual Head of Centre Declaration. The declaration is confirmation from a centre that it has taken reasonable steps to ensure that each learner entered for a particular assessment series has completed the prescribed practical activities for the practical endorsement (as specified in Appendix B of this specification).

If a centre fails to submit an Annual Head of Centre Declaration for an assessment series then it will be treated as a case of malpractice and/or maladministration.

Centres must have systems in place that enable them to ensure that private candidates have completed the required specified practical activities. It will be the responsibility of the centre entering private learners to validate that these candidates have completed the required specified practical activities.

4 TECHNICAL INFORMATION

4.1 Making entries

This is a linear qualification in which all assessments must be taken at the end of the course. Assessment opportunities will be available in May/June each year, until the end of the life of this specification. Summer 2019 will be the first assessment opportunity.

Where learners wish to re-sit the qualification, all components must be re-taken.

The entry code appears below.

WJEC Eduqas A level Geology: A480QS

The current edition of our *Entry Procedures and Coding Information* gives up-to-date entry procedures.

4.2 Grading, awarding and reporting

A level qualifications are reported as a grade from A* to E. Results not attaining the minimum standard for the award will be reported as U (unclassified).

APPENDIX A

Working scientifically

The lists below outline the range and extent of practical skills and techniques required by WJEC Eduqas A level in Geology. These represent the skills and techniques outlined in the *Department for Education GCE AS and A level subject content for Geology* document (Appendix 1a, 1b and 1c).

Practical skills can be split into:

- those which are assessed indirectly through written examinations (outlined in Part 1)

- those which will be assessed directly by teachers through appropriate practical activities (outlined in Part 2) for the practical endorsement.

Part 3 documents the techniques which learners must complete in order to demonstrate their competency in the practical skills in Part 2, for the practical endorsement.

<u>Part 1</u> - Practical skills identified for indirect assessment and developed through teaching and study

Question papers will assess learners' abilities to:

Independent thinking

- solve problems set in geological contexts
- apply geological knowledge to practical contexts

Use and application of scientific methods and practices

- comment on investigation design and evaluate scientific methods
- present data in appropriate ways
- evaluate results and draw conclusions with reference to measurement uncertainties and errors
- identify variables including those that must be controlled

Numeracy and the application of mathematical concepts in a practical context

- plot and interpret graphs
- process and analyse data using appropriate mathematical skills as exemplified in the mathematical appendix (see Appendix C)
- consider margins of error, accuracy and precision of data

Instruments and equipment

- know and understand how to use a wide range of experimental and practical instruments, equipment and techniques appropriate to the knowledge and understanding included in the specification.

<u>Part 2</u> - Practical skills identified for direct assessment and developed through teaching and study

Practical work carried out throughout the course will enable learners to develop the following skills.

Independent thinking

- apply investigative approaches and methods to practical work

Use and apply scientific methods and practices

- safely and correctly use a range of practical equipment and materials
- follow written instructions
- make and record observations
- keep appropriate records of practical activities, including investigative activities
- present geological information and data in a scientific way
- use appropriate software and tools to process data, carry out research and report findings

Research and referencing

- use online and offline research skills including websites, textbooks and other printed scientific sources of information
- correctly cite sources of information

Instruments and equipment

- use a wide range of investigative and practical instruments, equipment and techniques appropriate to the knowledge and understanding included in the specification.

<u>Part 3</u> – Use of apparatus and techniques

Practical techniques to be completed by learners:

- location of geological features in the field using traditional navigation and basic field survey skills without the use of GPS*
- identification of geological structures in the field recording observations as field sketches*
- use of a compass clinometer to measure two and three-dimensional geological data across a range of scales such as the dip and strike of planar surfaces, or the apparent dip of fold limbs exposed on a hillside or cliff section*
- construct graphic logs using appropriate scale and symbol sets for unfamiliar geological sequences and exposures*
- use sampling techniques in fieldwork*
- apply classification systems using distinguishing characteristics to identify unknown minerals and fossils
- produce annotated scientific drawing of fossils, or small scale features, from hand samples using a light microscope, or hand lens observation
- produce full rock description of macro and micro features from conserved hand samples and unfamiliar field exposures*
- use of photomicrographs to identify minerals and rock textures
- use appropriate apparatus to record a range of quantitative measurements (to include mass, time, volume, temperature and length)

- use of physical and chemical testing to identify minerals to include:
  - density test
  - Mohs hardness test

- use methods to increase accuracy of measurements, such as timing over multiple observations, or use of a fiducial (scale in photograph/field sketch)

- use of ICT to:
  - compile and analyse geological data sets through to visualization using geographic information system (GIS)
  - collect, process and model geological data

* Fieldwork skills indicated in the list above are to be carried out at unfamiliar field exposures.

APPENDIX B

Practical technique requirements and exemplification

Appendix B has been divided into three parts.

- Part 1 lists the specified practical activities required to fulfil the practical endorsement. The code aids mapping of the practical activity within the 'Geological techniques and skills' column of the subject content within the specification
- Part 2 lists the practical technique requirements and maps them against the specified practical activities
- Part 3 lists the apparatus required to fulfil the specified practical activities

Part 1 Specified practical activities to fulfil the practical endorsement

Code	Specified practical activity
SP1	Investigation of diagnostic properties of minerals: colour, crystal shape, cleavage, fracture, hardness, relative density, streak, lustre, reaction with cold dilute (0.5 mol dm^{-3}) hydrochloric acid in order to identify minerals.
SP2	Measurement of the density of minerals.
SP3	Application of classification systems using distinguishing characteristics to identify unknown minerals.
SP4	Production of scaled annotated scientific drawings of rock samples from hand samples using a light microscope, or hand lens observation.
SP5	Production of full rock description of macro and micro features from hand specimens and unfamiliar field exposures of sedimentary rocks in order to interpret component composition, colour and textures, to identify rock types and to deduce their environment of deposition.
SP6	Construction of graphic logs using appropriate scale and symbol sets for unfamiliar geological sequences and exposures to record data relevant to an investigation.
SP7	Use of photomicrographs to identify minerals and rock textures of sedimentary rocks in order to identify rock types and to deduce their environment of deposition.
SP8	Production of full rock description of macro and micro features from hand specimens and/or unfamiliar field exposures of igneous rocks in order to interpret component composition, colour and textures, to identify rock type and to deduce their cooling history.
SP9	Use of photomicrographs to identify minerals and rock textures of igneous rocks to identify rock type and to deduce their cooling history.

SP10	Production of full rock description of macro and micro features from hand specimens and/or unfamiliar field exposures of metamorphic rocks in order to interpret component composition, colour and textures, to identify rock type and to deduce the temperature and pressure conditions of their formation.
SP11	Use of photomicrographs to identify minerals and rock textures of metamorphic rocks to identify rock type and to deduce the temperature and pressure conditions of their formation.
SP12	Location of geological features onto a base map.
SP13	Identification of the location of geological features in the field using six figure grid references on maps.
SP14	Production of scaled, annotated field sketches at unfamiliar field exposures to record data relevant to an investigation.
SP15	Measurement of dip and strike elements: dip angle, dip and strike directions of planar surfaces, relevant to an investigation.
SP16	Application of classification systems using distinguishing characteristics to identify unknown fossils.
SP17	Production of scaled, annotated scientific drawings of fossils, using a light microscope, or hand lens observation.
SP18	Measurement of densities of representative samples of Earth layers (e.g granite, basalt).
SP19	Investigation of the relationships between earthquake data (focal depth, magnitude and distance from plate boundaries) using data on Google Earth™.
SP20	Investigation of contact metamorphism using the Metamorphic Aureole simulation experiment.

Part 2 Practical technique requirements and exemplification

Practical Technique	Specified practical activities which exemplify the practical technique
Location of geological features in the field using traditional navigation and basic field survey skills without the use of GPS.	SP12: Location of geological features onto a base map. SP13: Identification of the location of geological features in the field using six figure grid references on maps.
Identification of geological structures in the field recording observations as field sketches.	SP14: Production of scaled, annotated field sketches at unfamiliar field exposures to record data relevant to an investigation.
Use of a compass clinometer to measure two and three-dimensional geological data across a range of scales such as the dip and strike of planar surfaces, or the apparent dip of fold limbs exposed on a hillside or cliff section.	SP15: Measurement of dip and strike elements: dip angle, dip and strike directions of planar surfaces, relevant to an investigation.
Construct graphic logs using appropriate scale and symbol sets for unfamiliar geological sequences and exposures.	SP6: Construction of graphic logs using appropriate scale and symbol sets for unfamiliar geological sequences and exposures to record data relevant to an investigation.
Use sampling techniques in fieldwork.	SP6: Construction of graphic logs using appropriate scale and symbol sets for unfamiliar geological sequences and exposures to record data relevant to an investigation.
Apply classification systems using distinguishing characteristics to identify unknown minerals and fossils.	SP16: Application of classification systems using distinguishing characteristics to identify unknown fossils. SP3: Application of classification systems using distinguishing characteristics to identify unknown minerals.
Produce annotated scientific drawing of fossils, or small scale features, from hand samples using a light microscope, or hand lens observation.	SP17: Production of scaled, annotated scientific drawings of fossils, using a light microscope, or hand lens observation. SP4: Production of scaled annotated scientific drawings of rock samples from hand samples using a light microscope, or hand lens observation.

Produce full rock description of macro and micro features from conserved hand samples and unfamiliar field exposures.	SP8: Production of full rock description of macro and micro features from hand specimens and/or unfamiliar field exposures of igneous rocks in order to interpret component composition, colour and textures, to identify rock type and to deduce their cooling history. SP10: Production of full rock description of macro and micro features from hand specimens and/or unfamiliar field exposures of metamorphic rocks in order to interpret component composition, colour and textures, to identify rock type and to deduce the temperature and pressure conditions of their formation. SP5: Production of full rock description of macro and micro features from hand specimens and unfamiliar field exposures of sedimentary rocks in order to interpret component composition, colour and textures, to identify rock types and to deduce their environment of deposition.
Use of photomicrographs to identify minerals and rock textures.	SP9: Use of photomicrographs to identify minerals and rock textures of igneous rocks to identify rock type and to deduce their cooling history. SP11: Use of photomicrographs to identify minerals and rock textures of metamorphic rocks to identify rock type and to deduce the temperature and pressure conditions of their formation. SP7: Use of photomicrographs to identify minerals and rock textures of sedimentary rocks in order to identify rock types and to deduce their environment of deposition.

Use appropriate apparatus to record a range of quantitative measurements (to include mass, time, volume, temperature and length).	SP2: Measurement of the density of minerals. SP18: Measurement of densities of representative samples of Earth layers (e.g. granite, basalt). SP14: Production of scaled, annotated field sketches at unfamiliar field exposures to record data relevant to an investigation. SP17: Production of scaled, annotated scientific drawings of fossils, using a light microscope, or hand lens observation. SP4: Production of scaled annotated scientific drawings of rock samples from hand samples using a light microscope, or hand lens observation. SP6: Construction of graphic logs using appropriate scale and symbol sets for unfamiliar geological sequences and exposures to record data relevant to an investigation. SP20: Investigation of contact metamorphism using the Metamorphic Aureole simulation experiment.
Use of physical and chemical testing to identify minerals to include: • density test • Mohs hardness test.	SP1: Investigation of diagnostic properties of minerals: colour, crystal shape, cleavage, fracture, hardness, relative density, streak, lustre, reaction with cold dilute (0.5 mol dm^{-3}) hydrochloric acid in order to identify minerals. SP2: Measurement of the density of minerals.
Use methods to increase accuracy of measurements, such as timing over multiple observations, or use of a fiducial (scale in photograph/field sketch)	SP14: Production of scaled, annotated field sketches at unfamiliar field exposures to record data relevant to an investigation. SP17: Production of scaled, annotated scientific drawings of fossils, using a light microscope, or hand lens observation. SP4: Production of scaled annotated scientific drawings of rock samples from hand samples using a light microscope, or hand lens observation. SP20: Investigation of contact metamorphism using the Metamorphic Aureole simulation experiment.

Use of ICT to: • compile and analyse geological data sets through to visualization using geographic information system (GIS) • collect, process and model geological data	SP19:Investigation of the relationships between earthquake data (focal depth, magnitude and distance from plate boundaries) using data on Google Earth™

Part 3 List of apparatus

The following list documents the apparatus required to fulfil the specified practical activities.

- hand lens
- streak plate/unglazed tile
- steel pin/needle, e.g. biology dissection pin or steel nail (5.5 on Mohs' Scale)
- copper coin
- cold, dilute hydrochloric acid 0.5 Mol dm^{-3}
- water and a means of adding it dropwise to a sample, e.g. dropping bottle/teat pipette, etc.
- spring balance (or eureka can and electronic balance)
- light microscope (optional)
- grain size card
- tape measure or metre rule
- compass
- clinometer
- large and small tins/containers
- sand
- polystyrene tile
- thermometers
- stopwatch/timer

APPENDIX C

Use of mathematical skills

The list below outlines the range and extent of mathematical skills required by WJEC Eduqas A level in Geology. The specific exemplifications are to aid understanding and could be developed in other areas of the specification content. Learners will be expected to apply mathematical skills in novel contexts.

Mathematical skills	Exemplification in the context of A level Geology
Number	
Recognise and make use of appropriate units in calculations	• convert between units e.g. ppb to gram per tonne • as part of calculations for gold ore concentration factor • work out the unit for a rate e.g. sedimentation rate
Recognise and use expressions in decimal and standard form	• use an appropriate number of decimal places in calculations e.g. for a mean • carry out calculations using numbers in standard and decimal form e.g. use of magnification • convert between numbers in standard and decimal form • understand that significant figures need retaining when making conversions between standard and decimal form e.g. 0.063 mm is equivalent to 6.3×10^{-2} mm
Use an appropriate number of significant figures	• report calculations to an appropriate number of significant figures given raw data quoted to varying numbers of significant figures. i.e. the answer is expressed to the same number of significant figures as the numbers involved in the calculation e.g. $5.71 \times 1.26 = 7.19$. If the numbers involved have a different number of significant figures then it is the lowest number of significant figures used that the answer is expressed to e.g. $5.7 \times 1.26 = 7.2$ • understand that calculated results can only be reported to the limits of the least accurate measurement
Use ratios, fractions and percentages	• calculate percentage yields • calculate percentage crustal shortening • calculate surface area to volume ratio • use scales for measuring
Make order of magnitude calculations	• use and manipulate the magnification formula $\text{magnification} = \dfrac{\text{size of image}}{\text{size of real object}}$

Estimate results	• estimate results to sense check that the calculated values are appropriate
Statistics and probability	
Find arithmetic means	• find the mean of a range of data e.g. the mean clast size
Construct and interpret frequency tables and diagrams, bar charts and histograms	• represent a range of data in a table with clear headings, units and consistent decimal places • interpret data from a variety of tables e.g. data relating intrusive dykes • plot a range of data in an appropriate format e.g. grain size distribution as a cumulative frequency graph • interpret data for a variety of graphs e.g. explain seismograph traces
Understand simple probability	• use the terms probability and chance appropriately • understand the probability associated with return periods for geohazards
Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are combined	• calculate percentage error where there are uncertainties in measurement
Understand the principles of sampling as applied to scientific data	• estimate optimum sample size from a plot of number of clasts sampled against running mean of mean b-axis length
Understand the terms mean, median and mode	• calculate or compare the mean, median and mode of a set of linear data e.g. Folk and Ward graphic statistics from sieve analysis of sand samples from different sedimentary environments. • calculate (graphically) or compare vector mean, median and mode of a set of circular data e.g. palaeocurrent directions in an Aeolian sandstone
Know the characteristics of normal and skewed distributions	• being presented with a set of data for crystal size in an igneous intrusion and being asked to indicate the position of the mean (or median, or mode) • interpret size analysis data from sieving of different sands
Understand measures of dispersion, including standard deviation and interquartile range	• calculate the standard deviation • understand why interquartile range might be a more useful measure of dispersion for a given set of data than standard deviation e.g. where there is an extreme observation which is part of the inherent variation

Plot two variables from experimental or other linear data	• select an appropriate format for presenting data: bar charts, histograms, graphs, triangular diagrams and scatter diagrams (scattergrams)
Use a scatter diagram to identify a correlation between two variables	• interpret a scatter diagram (scattergram) e.g. rate of plate motion against total length of subducting plate margin
Plot variables from experimental or other circular data	• select an appropriate format for presenting data, raw data plot, circular bar graph, rose diagram and polar equal area stereonet (polar plots only not projections or great circles)
Select and use a statistical test	• the chi squared test to test the significance of the difference between observed and expected results e.g. palaeocurrent data • the Mann-Witney U test e.g. clast sizes in two conglomerate beds • Spearman's rank correlation coefficient e.g. bed thickness and maximum clast size
Algebra and graphs	
Understand and use the symbols: =, <, <<, >>,>, α and ~	
Change the subject of an equation	• use and manipulate equations e.g. magnification, velocity, density
Substitute numerical values into algebraic equations using appropriate units for physical quantities	• use a given equation e.g. Darcy's law $Q = -kA\left(\frac{h_2 - h_1}{L}\right)$
Solve algebraic equations	• solve equations in a geological context e.g. $\varphi = -\log_2\left(\frac{D}{D_0}\right)$
Use calculators to find and use power, exponential and logarithmic functions	• solve for unknowns in radionuclide decay problems e.g. $N = N_0e^{-\lambda t}$
Use logarithms in relation to quantities that range over several orders of magnitude	• use a logarithmic scale in the context of geology e.g. decay law of radioactivity / Udden-Wentworth grain size scale
Translate information between graphical, numerical and algebraic forms	• understand that data may be presented in a number of formats and be able to use these data e.g. time distance curves for earthquakes
Understand that $y = mx + c$ represents a linear relationship	• predict/sketch the shape of a graph with a linear relationship e.g. burial curves in a sedimentary basin or the effect of intrusion size on the width of the baked margin
Determine the slope and intercept of a linear graph	• read off an intercept point from a graph e.g. the initial velocity of a velocity time graph for a density current

Calculate rate of change from a graph showing a linear relationship	• calculate a rate from a graph e.g. geothermal gradient through the lithosphere
Interpret logarithmic plots	• use logarithmic plots with decay law of radioactivity
Geometry and measures	
Calculate the circumferences, surface areas and volumes of regular shapes	• calculate the circumference and area of a circle • calculate the surface area and volume of rectangular prisms, of cylindrical prisms and of spheres e.g. calculate the surface area or volume of a longwall panel
Visualize and represent 2D and 3D forms, including 2D representations of 3D objects	• draw geological cross-sections interpreted from geological maps • interpret block diagrams to show geological structures in 3D • interpret field exposures and record 3D geological structures using a field sketch
Use sin, cos and tan in physical problems	• determine true thickness of rock units • interpret block diagrams to show geological structures in 3D • determine crustal extension or shortening

APPENDIX D

Scientific skills

Scientific skill	Areas of the specification which exemplify the scientific skill (assessment is not limited to the examples below)
Use theories, models and ideas to develop geological explanations	F1.1d F2.2a F2.3a F3.1a F3.1b F3.2a F3.2b F4.1a F4.2b G1.1a G1.1b G1.1c G1.2a G1.3a G1.3b G3.1a G3.1d G3.2a G3.3e G4.1d G4.2b
Use knowledge and understanding to pose scientific questions, define geological problems, present scientific arguments and geological ideas	F1.1g F2.1d F2.1e F2.1g F2.2b F2.2e F2.3a F2.3f F3.1b F3.1d F3.1g F3.2a F3.2b F4.1a F4.1b F4.2b G1.3a G1.3b G2.1c G2.1d G3.3a G3.3d G4.2a T1.1 T2.1 T2.2
Use appropriate methodology, including information and communication technology (ICT), to answer geological questions and solve geological problems	F1.1g F2.1d F2.1e F2.1g F2.2b F2.2e F2.3a F2.3f F2.3g F3.1b F3.1d F3.1g F3.2a F3.2b F4.1a F4.1b F4.2b G1.1b G1.1c G1.2a G1.2d G1.3a G1.3b G2.1c G2.1d G3.3a G3.3d G4.1d G4.2a G4.2b G4.3 T1.3 T2.1 T2.2
Carry out fieldwork, experimental and investigative activities in a range of contexts to include the collection, compilation and analysis of Earth Science data from the field and subsurface, and appropriate risk management.	F1.1e F2.1d F2.2b F2.2c F2.2e F2.3a F3.2a F4.1a G1.3b G4.1a G4.1b G4.1d G4.2c G4.3
Manipulate and extrapolate these sometimes incomplete data sets in both two and three-dimensions	F2.3 G2.1d G2.1e G4.1a G4.1b G4.1d G4.2c G4.3 T2.1 T2.2
Evaluate methodology, evidence and partial data sets, and resolve conflicting evidence	F2.1d F2.1e F2.1g F2.2b F2.2e F2.3a F2.3f F3.1b F3.1d F3.1g F3.2a F3.2b F4.1a F4.1b F4.2b G1.1a G1.1c G3.1b G1.3d G3.2b G3.2d T1.2c T2.1 T2.2
Communicate information and ideas in appropriate ways (including geological maps and cross-sections) using appropriate terminology, SI units and their prefixes and the ability to express in standard form	F2.2a F2.3 F4.1a F4.1b F4.2b G1.1a G1.1c G1.2a G3.2c G4.2c G4.3 T2.1 T2.2
Know that scientific knowledge and understanding develops over time , consider applications and implications of science in geology, and evaluate their associated benefits and risks	F4.2a F4.2b G1.1c G3.1b G3.1d G3.2d G3.3e
Evaluate the role of geology within the scientific community in validating new knowledge and ensuring integrity	F4.2a F4.2b G1.1c G3.1b G3.1d G3.2d G3.3e

APPENDIX E

SI units in geology

The International System of Units (Système International d'Unités), which is abbreviated as SI, is a coherent system of base units. The six which are relevant for AS and A level geology are listed below. We also list eight of the derived units (which have special names) selected from the SI list of derived units in the same source.

Base units
These units and their associated quantities are dimensionally independent: metre (m), kilogram (kg), second (s), ampere (A), kelvin (K) and mole (mol).

Some derived units with special names
Frequency hertz (Hz), force newton (N), energy joule (J), power watt (W), pressure pascal (Pa), electric charge coulomb (C), electric potential difference volt (V) and electric resistance ohm (Ω).

Some non-standard units used in geology
Time day (d), time year - annum (a) and mass tonne (t).