A LEVEL
Geology

Qualification Accredited

OCR
Oxford Cambridge and RSA

A LEVEL
Specification

GEOLOGY

H414
For first assessment in 2019

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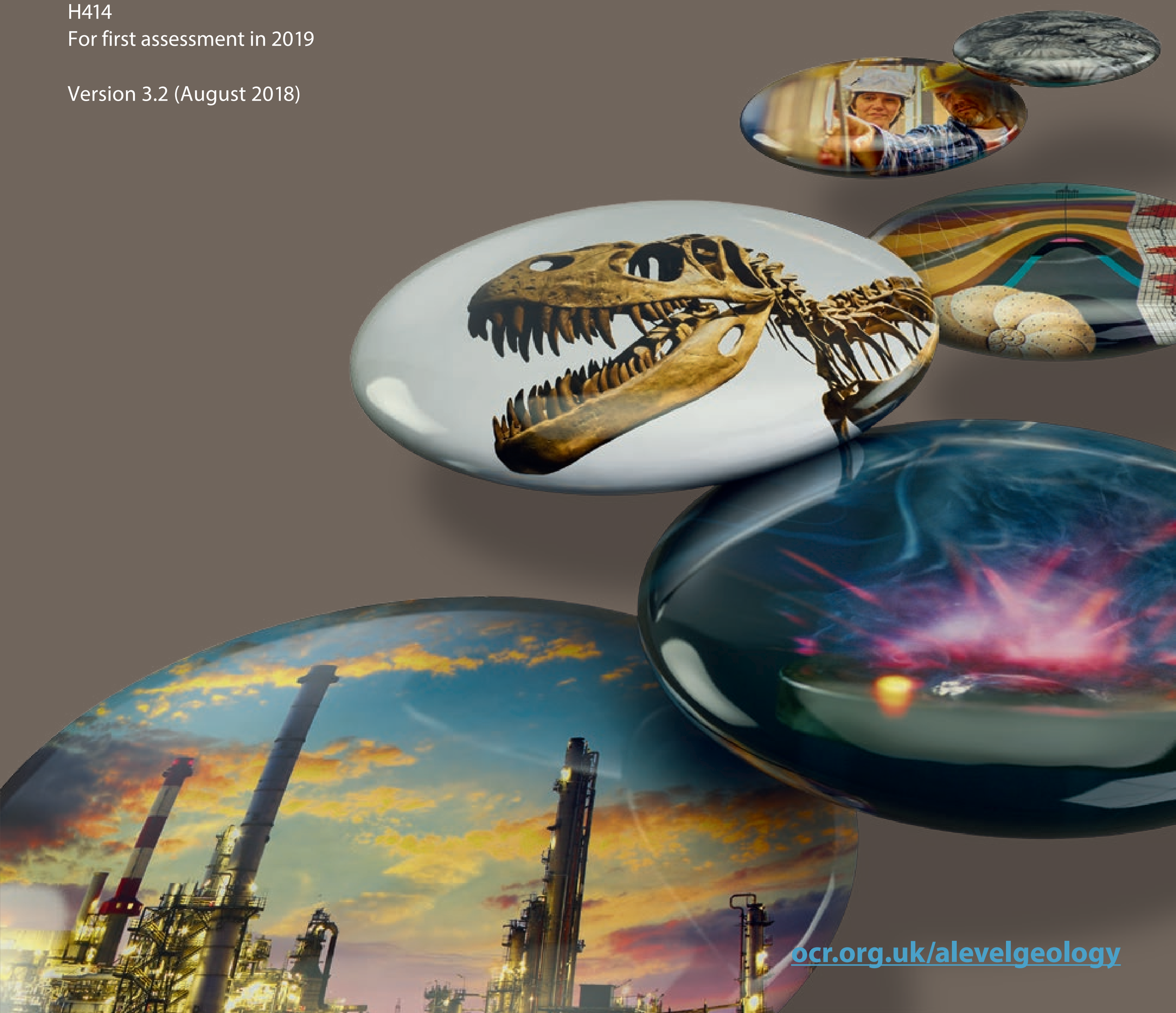

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We will inform centres about changes to specifications. We will also publish changes on our website. The latest version of our specifications will always be those on our website (ocr.org.uk) and these may differ from printed versions.

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1 Why choose an OCR A Level in Geology?

1a. Why choose an OCR qualification?

Choose OCR and you've got the reassurance that you're working with one of the UK's leading exam boards. Our new A Level in Geology course has been developed in consultation with teachers, employers and Higher Education to provide learners with a qualification that's relevant to them and meets their needs.

We're part of the Cambridge Assessment Group, Europe's largest assessment agency and a department of the University of Cambridge. Cambridge Assessment plays a leading role in developing and delivering assessments throughout the world, operating in over 150 countries.

We work with a range of education providers, including schools, colleges, workplaces and other institutions in both the public and private sectors. Over 13,000 centres choose our A Levels, GCSEs and vocational qualifications including Cambridge Nationals and Cambridge Technicals.

Our Specifications

We believe in developing specifications that help you bring the subject to life and inspire your learners to achieve more.

We've created teacher-friendly specifications based on extensive research and engagement with the teaching community. They're designed to be straightforward and accessible so that you can tailor the delivery of the course to suit your needs. We aim to encourage learners to become responsible for their own learning, confident in discussing ideas, innovative and engaged.

We provide a range of support services designed to help you at every stage, from preparation through to the delivery of our specifications. This includes:

- A wide range of high-quality creative resources including:
  - Delivery Guides
  - Transition Guides
  - Topic Exploration Packs
  - Lesson Elements
  - …and much more.
- Access to Subject Advisors to support you through the transition and throughout the lifetime of the specification.
- CPD/Training for teachers to introduce the qualification and prepare you for first teaching.
- Active Results – our free results analysis service to help you review the performance of individual learners or whole schools.

All A Level qualifications offered by OCR are accredited by Ofqual, the Regulator for qualifications offered in England. The accreditation number for OCR's A Level in Geology is QN 603/0782/1.

1b. Why choose an OCR A Level in Geology?

The OCR A Level Geology allows learners to first assimilate a toolkit of geological skills and concepts, before developing their understanding through study of geological principles and application to relevant real-life contexts. The specification allows flexibility in the teaching approach. Teaching of practical skills is integrated with the theoretical topics, and these skills are assessed through written papers and, for A Level only, the Practical Endorsement.

All of our specifications have been developed with subject and teaching experts. We have worked in close consultation with teachers and representatives from Higher Education (HE) with the aim of including up-to-date relevant content within a framework that is interesting to teach and administer within all centres (large and small).

Our new A Level in Geology qualification builds on our existing course and offers familiarity to existing centres but is also clear and logically laid out for centres new to OCR, with an assessment model that is straightforward to administer.

The re-development of our A Level Geology qualification has been aligned with the popular OCR A Level science suite B [Biology B (Advancing Biology), Chemistry B (Salters) and Physics B (Advancing Physics)]. It is based on an understanding of what works well in centres large and small. Areas of content have been updated where stakeholders have identified that improvements could be made. We have undertaken a significant amount of consultation through our science forums (which include representatives from learned societies, HE, teaching and industry) and through focus groups with teachers.

We have worked closely with teachers and HE representatives to provide high quality support materials to guide you through the new qualifications.

Aims and learning outcomes

OCR's A Level in Geology will encourage 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
- develop and apply core knowledge and understanding, and use this understanding synoptically and applied to relevant contexts
- 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.

1c. What are the key features of this specification?

The OCR A Level in Geology has been designed to inspire your learners, develop their interest in, and enthusiasm for, the subject and uses an engaging, flexible approach.

The specification:

- places a particular emphasis on the development of practical skills and geological literacy
- is laid out clearly in a series of teaching modules with Additional guidance added where required to clarify assessment requirements
- is structured to allow ideas to be introduced within relevant and contemporary settings that help learners anchor their conceptual knowledge of the range of topics required at A Level
- is co-teachable with the AS Level
- embeds practical requirements within the teaching modules
- identifies Practical Endorsement requirements and how these can be integrated into teaching of content (see Section 5g)
- exemplifies the mathematical requirements of the course (see Section 5e)
- highlights opportunities for the introduction of key mathematical requirements (see Section 5e and the Additional guidance column for each module) into your teaching
- identifies, within the Additional guidance, how the skills, knowledge and understanding of How Science Works (HSW) can be incorporated within teaching.

Teacher support

The extensive support offered alongside this specification includes:

- **delivery guides –** providing information on assessed content, the associated conceptual development and contextual approaches to delivery
- **transition guides –** identifying the levels of demand and progression for different key stages for a particular topic and going on to provide links to high quality resources and 'checkpoint tasks' to assist teachers in identifying learners 'ready for progression'
- **lesson elements –** written by experts, providing all the materials necessary to deliver creative classroom activities
- **Active Results** (see Section 1a)

Along with:

- Subject Advisors within the OCR science team to help with course queries
- teacher training
- *Science Spotlight* (our termly newsletter)
- OCR Science community, http://social.ocr.org.uk/
- a consultancy service (to advise on Practical Endorsement requirements) pass@ocr.org.uk
- Practical Skills Handbook
- Maths Skills Handbook.

1d. What is new in OCR A Level in Geology?

This section is intended for teachers currently delivering OCR A Level in Geology. It highlights the differences between the A Level in Geology (H487) and the A Level in Geology (H414) for first teaching from September 2017:

What stays the same?	What's changing?
• Assessment is at the end of the course • Co-teachable with the AS Level Geology, which covers the first year of the A Level course content • Assumes no previous experience of geology and develops concepts and ideas from GCSE (9–1) Science in the context of Earth science • Content is familiar, although updated and streamlined • The second year of the course studies economic geology, engineering geology, geohazards and applied palaeontology; content and approach updated in consultation with HE to reflect the role of geologists in the contemporary world • Key topic areas have stayed the same including palaeontology with increased emphasis on application of ideas • Breadth of mathematical coverage.	• The assessment consists of a three exams, with a total of 6 hours of assessment time • Direct assessment of practical skills in the Practical Endorsement, follows a common model across the OCR GCE Science Suite • Course redesigned to give learners a toolkit of geological skills and conceptual knowledge in the first year • Reintroduced mineralogy and geochemistry, with advanced petrology concepts moved to the second year • In the second year ideas are applied and developed within relevant and contemporary contexts • Fieldwork requirement (four days) and indirect assessment of practical skills in examination (15% weighting) • 10% Level 2 maths weighting.

1e. How do I find out more information?

If you are already using OCR specifications you can contact us at: www.ocr.org.uk

If you are not already a registered OCR centre then you can find out more information on the benefits of becoming one at: www.ocr.org.uk

If you are not yet an approved centre and would like to become one go to: www.ocr.org.uk

Find out more?

Contact the Subject Advisors:
ScienceGCE@ocr.org.uk, 01223 553998

Join our Science community: http://social.ocr.org.uk/

Check what CPD events are available:
www.cpdhub.ocr.org.uk

Follow us on Twitter: @ocr_science

2 The specification overview

2a. OCR's A Level in Geology (H414)

Learners take all components: 01, 02, 03 and 04 to be awarded the OCR A Level in Geology.

Content Overview	Assessment Overview	
Content is split into seven teaching modules: • Module 1 – Development of practical skills in geology • Module 2 – Foundations in geology • Module 3 – Global tectonics • Module 4 – Interpreting the past • Module 5 – Petrology and economic geology • Module 6 – Geohazards • Module 7 – Basin analysis Components 01–03 assess content from all seven modules.	Fundamentals of geology* (01) 110 marks 2 hour 15 minutes written paper	**41%** of total A Level
	Scientific literacy** in geology* (02) 100 marks 2 hour 15 minutes written paper	**37%** of total A Level
	Practical skills in geology* (03) 60 marks 1 hour 30 minutes written paper	**22%** of total A Level
	Practical endorsement in geology (04) (non-exam assessment)	**Reported separately** (see Section 5g)

*Indicates inclusion of synoptic assessment. See Section 3f.

**'Scientific literacy' means the ability to comprehend a passage of text of A Level standard, to extract information from it and to use this information (see Section 2e).

2b. Content of A Level in Geology (H414)

The A Level in Geology specification content is divided into seven teaching modules and each module is further divided into key topics.

Each module is introduced with a summary which contextualises the geology it contains and each topic is also introduced with a short summary text. These do not form part of the assessable content. It is expected that contexts are used in teaching to relate the subject to real-world geological experience. Learners will be expected to be able to apply their understanding of Geology to both familiar and unfamiliar contexts in the assessments.

The assessable content is divided into two columns: Learning outcomes and Additional guidance.

The Learning outcomes may all be assessed in the examinations (with the exception of some of the skills in module 1.2 which will be assessed directly through the Practical Endorsement). The Additional guidance column is included to provide further advice on delivery and the expected skills required from learners.

References to How Science Works (HSW, Section 5d) are included in the guidance to highlight opportunities to encourage a wider understanding of science.

The mathematical skills requirements (Section 5e), are referenced by the prefix M to link the mathematical skills required for A Level Geology to examples of geology content where those mathematical skills could be linked to learning. Skills that will be tested only in the full A Level course are given in bold.

References to HSW statements and mathematical skills are indicative of where these skills could be developed, and are not intended to be either prescriptive or exhaustive. Where learning outcomes comprise several sub-statements, references relevant to any of the sub-statements have been grouped.

The specification has been designed to be co-teachable with the standalone AS Level in Geology qualification. The first four modules comprise the AS Level in Geology course and learners studying the A Level continue with the content of modules 5 to 7. The internally assessed Practical Endorsement skills also form part of the full A Level (see module 1.2).

A summary of the content for the A Level course is as follows:

Module 1 – Development of practical skills in geology

- Practical skills assessed in a written examination
- Practical skills assessed in the Practical Endorsement
- Practical skills developed through fieldwork and assessed in a written examination

Module 2 – Foundations in geology

- Minerals and rocks
- Fossils and time

Module 3 – Global tectonics

- Earth structure
- Plate tectonics
- Geological structures

Module 4 – Interpreting the past

- Sedimentary environments in time
- Geochronology

Module 5 – Petrology and economic geology

- Applied sedimentology
- Fluids and geological processes
- Igneous petrology
- Metamorphic petrology
- Mining geology

Module 6 – Geohazards

- Geohazards
- Engineering geology

Module 7 – Basin analysis

- Key concepts for basin analysis
- Basin analysis in practice

Assessment of practical skills and the Practical Endorsement

Module 1 of the specification content relates to the practical skills learners are expected to gain throughout the course, which are assessed throughout the written examinations and also through the Practical Endorsement (see Section 5g). In the written examinations, a minimum of 15% of the total marks for the qualification will assess knowledge and understanding in relation to practical skills.

Practical activities are embedded within the learning outcomes of the course to encourage practical activities in the classroom which contribute to the achievement of the Practical Endorsement (Section 5g) as well as enhancing learners' understanding of geological theory and practical skills.

Opportunities for carrying out activities that could count towards the Practical Endorsement are indicated throughout the specification. These are shown in the Additional guidance column as **PAG1** to **PAG10** and **PAG12** (Practical Activity Group, see Section 5g). These references are not intended to be either prescriptive or exhaustive. Where learning outcomes comprise several sub-statements, references relevant to any of the sub-statements have been grouped.

There are a wide variety of opportunities to assess **PAG11** throughout the qualification.

Fieldwork skills

Fieldwork skills are fundamental to the study, practice and discipline of geology. They are integrated into all aspects of the subject. Learning these skills in the context of the content detailed in Section 2c will stimulate learners to 'think geologically'. It will also provide them with opportunities to apply the skills in a wide range of curriculum or learning contexts.

Conducting fieldwork as part of a varied learning programme allows learners to achieve skills such as the ability to visualise and extrapolate data in three dimensions, and to understand the application of practical methodologies.

Within the A Level Geology course, learners are required to undertake a **minimum of four days** of fieldwork (see Section 4a). This fieldwork should allow learners to develop proficiency in the skills, apparatus and techniques covered by the Practical Endorsement (see module 1.2) and to demonstrate their competence in practical field geology. Specific fieldwork skills that learners must undertake and that have been identified for indirect assessment are detailed in module 1.3.

Individual fieldwork activities may combine development of the skills listed in modules 1.1 and 1.3, and assessment of the skills, apparatus and techniques covered by the Practical Endorsement (module 1.2).

2c. Content of modules 1 to 7

Module 1: Development of practical skills in geology

The development of practical skills is a fundamental and integral aspect of the study of any scientific subject and a common approach has been adopted across the OCR science suite (Biology, Chemistry, Geology and Physics). These skills not only enhance learners' understanding of the subject but also serve as a suitable preparation for the demands of studying geology at a higher level.

Geology gives learners many opportunities to develop the fundamental skills needed to collect and analyse empirical data. Skills in planning, implementing, analysing and evaluating (as outlined in 1.1) and fieldwork skills (as outlined in 1.3) will be assessed in the written papers.

1.1 Practical skills assessed in a written examination

The practical skills detailed in module 1.1 are embedded throughout modules 2 to 7 of this specification.

Learners will be required to develop a range of practical skills throughout their course. The practical skills assessed in written examinations will be assessed in contexts both familiar and unfamiliar to the learners.

1.1.1 Planning

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	experimental design, including to solve problems set in a practical context	Including selection of suitable apparatus, equipment and techniques for the proposed experiment. Learners should be able to apply scientific knowledge based on the content of the specification to the practical context. HSW3
(b)	identification of variables that must be controlled, where appropriate	
(c)	evaluation that an experimental method is appropriate to meet the expected outcomes.	HSW6

1.1.2 Implementing

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	how to use a wide range of practical apparatus and techniques correctly	As outlined in the content of the specification and the skills required for the Practical Endorsement. HSW4
(b)	appropriate units for measurements	*M1.1*
(c)	presenting observations and data in an appropriate format.	*M1.1* HSW8

1.1.3 Analysis

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	processing, analysing and interpreting qualitative and quantitative experimental results	Including reaching valid conclusions, where appropriate. HSW5
(b)	use of appropriate mathematical skills for analysis of quantitative data	Refer to Section 5e for a list of mathematical skills that learners should have acquired competence in as part of their course. HSW3
(c)	appropriate use of significant figures	*M1.3*
(d)	plotting and interpreting suitable graphs from experimental results, including: **(i)** selection and labelling of axes with appropriate scales, quantities and units **(ii)** measurement of gradients and intercepts.	*M2.9, M2.10, M3.7, M3.8,* ***M3.9****, M3.10,* ***M3.11***

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1.1.4 Evaluation

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	how to evaluate results and draw conclusions	HSW6
(b)	the identification of anomalies in experimental measurements	
(c)	the limitations in experimental procedures	
(d)	precision and accuracy of measurements and data, including margins of error, percentage errors and uncertainties in apparatus	***M2.4***
(e)	the refining of experimental design by suggestion of improvements to the procedures and apparatus.	HSW3

1.2 Practical skills assessed in the Practical Endorsement

Note that this section is not relevant to the AS Level course.

A range of practical experiences is a vital part of a learner's development as part of this course.

Learners should develop and practise a wide range of practical skills throughout the course as preparation for the Practical Endorsement, as well as for the written examinations. The Practical Endorsement in Geology is set out to reflect the assessment across the OCR science suite (Biology, Chemistry, Geology and Physics).

The experiments and skills required for the Practical Endorsement will allow learners to develop and practise their practical skills, preparing learners for the written examinations. Opportunities for those practical skills assessed in the Practical Endorsement are embedded throughout modules 2 to 7 of this specification.

Please refer to Section 5g (the Practical Endorsement) in this specification to see the list of practical experiences all learners should cover during their course. Further advice and guidance on the Practical Endorsement can be found in the Practical Skills Handbook.

1.2.1 Practical skills

	Learning outcomes	Additional guidance
	Practical work carried out throughout the course will enable learners to develop the following skills:	
Independent thinking		
(a)	apply investigative approaches and methods to practical work	Including how to solve problems in a practical context. HSW4
Use and application of scientific methods and practices		
(b)	safely and correctly use a range of practical equipment and materials	See Section 5g. Including identification of potential hazards. Learners should understand how to minimise the risks involved. HSW4
(c)	follow written instructions	
(d)	make and record observations/measurements	HSW8
(e)	keep appropriate records of experimental activities	See Section 5g.
(f)	present information and data in a scientific way	HSW8
(g)	use appropriate software and tools to process data, carry out research and report findings	*M3.1* HSW3
Research and referencing		
(h)	use online and offline research skills including websites, textbooks and other printed scientific sources of information	
(i)	correctly cite sources of information	The Practical Skills Handbook provides guidance on appropriate methods for citing information.
Instruments and equipment		
(j)	use a wide range of experimental and practical instruments, equipment and techniques appropriate to the knowledge and understanding included in the specification.	See Section 5g. HSW3, HSW4

1.2.2 Use of apparatus and techniques

	Learning outcomes	Additional guidance
	Through use of the apparatus and techniques listed below, and a minimum of 12 assessed practicals (see Section 5g), learners should be able to demonstrate all of the practical skills listed within 1.2.1 and the Common Practical Assessment Criteria (CPAC, Section 5g, ***Table 2****) as exemplified through:*	
(a)*	location of geological features in the field using traditional navigation and basic field survey skills without the use of GPS	HSW4
(b)*	identification of geological structures in the field, recording observations as field sketches	HSW4
(c)*	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	HSW4
(d)*	construction of graphic logs using appropriate scale and symbol sets for unfamiliar geological sequences and exposures	HSW4
(e)*	use of sampling techniques in fieldwork	HSW3,4
(f)	application of classification systems using distinguishing characteristics to identify unknown minerals and fossils	HSW4
(g)	production of annotated scientific drawings of fossils, or small scale features, from hand samples using a light microscope, or hand lens observation	HSW4,8
(h)*	production of full rock descriptions of macro and micro features from conserved hand samples and unfamiliar field exposures	HSW4,8,10
(i)	use of photomicrographs to identify minerals and rock textures	HSW4,5
(j)	use of appropriate apparatus to record a range of quantitative measurements (to include mass, time, volume, temperature and length)	HSW4

	Learning outcomes	Additional guidance
(k)	use of physical and chemical testing to identify minerals to include: **(i)** density test **(ii)** Mohs hardness test	HSW4,10
(l)*	use of methods to increase accuracy of measurements, such as timing over multiple observations, or use of a fiducial scale (in photograph/field sketch)	HSW4
(m)	use of ICT to: **(i)** compile and analyse geological data sets to enable visualisation using geographic information system (GIS) **(ii)** collect, process and model geological data.	HSW3,4,8

Learners must be given the opportunity to demonstrate the skills in Section 1.2.2 marked with an asterisk (*) on unfamiliar outcrop geology.

1.3 Practical skills developed through fieldwork and assessed in a written examination

Development of fieldwork skills is a vital part of a learner's development as part of this course. Relevant contexts for the development of fieldwork skills are included throughout all modules of the specification.

A minimum of four days of fieldwork conducted throughout the course will allow learners to undertake the following techniques (see Section 4a).

Learners should conduct their fieldwork responsibly, showing awareness for their own safety and of their impact on the environment.

As part of the A Level Geology course, learners are required to:

- undertake fieldwork in different contexts: virtual fieldwork, local fieldwork outside the classroom and fieldwork on unfamiliar outcrop geology
- apply knowledge and concepts to identify and understand field observations.

1.3.1 Practical skills developed through fieldwork

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	the measurement and description of the diagnostic properties of rocks in the field	To include: colour, composition, grain/crystal size and grain/crystal shape and sorting/ igneous texture/metamorphic fabric. *M1.1, M2.1, M2.2, **M2.4**, M2.6, **M2.7**, M2.8, **M4.1**, M4.2* HSW4,10
(b)	the collection of valid data in the field relating to the igneous, metamorphic or sedimentary processes that formed the rocks	To include: random, stratified and systematic sampling techniques and sampling validity. *M2.5* HSW4,10
(c)	the measurement and description of rock deformation in the field	To include sampling validity. *M1.1, M2.4, M2.5, M4.2, **M4.3*** HSW4,10
(d)	the use of geochronological principles in the field to place geological events in relative time sequences.	HSW4,10

Module 2: Foundations in geology

Like all sciences, Earth science is a broad discipline and geologists commonly work in multidisciplinary teams. Modules 2, 3 and 4 will be familiar to all geologists.

Taking a major oil development as an example of a multidisciplinary team: geologists explore for the oil (petroleum geology), use fossils to date the rocks (palaeontology), determine the ground conditions for construction (engineering geology), design the structures needed to recover the oil (civil engineering), find the bulk minerals needed for the project (mining geology) and use water to maximise hydrocarbon recovery (hydrogeology).

This section provides knowledge and understanding of minerals, rocks, fossils and the geological timescale. It builds on learners' knowledge of Earth science and places this within a scientific framework.

Learners will have knowledge of the geological phenomena from place-based study in geography, and relevant scientific principles from GCSE (9–1) Science.

This section aims to provide learners with a basic geological toolkit grounded in their hands-on experience of rocks and fossils (2.1 Minerals and rocks, 2.2 Fossils and time).

Learners are expected to apply knowledge, understanding and other skills developed in this module to new situations and/or to solve related problems.

2.1 Minerals and rocks

'The best geologist is the one who has seen the most rocks.' – Prof. H. H. Read

Minerals are the basic components of geology; all rocks contain one or more minerals. The understanding of minerals builds on learners' existing knowledge of chemistry and physics.

Knowledge of igneous, sedimentary and metamorphic rocks based on the handling and description of rock samples prepares learners for the study of modules 3 to 7.

2.1.1 Minerals

The chemical composition and crystalline structure of rock-forming minerals determine their diagnostic characteristics and behaviour.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	minerals as naturally occurring elements and inorganic compounds whose composition can be expressed as a chemical formula	To include: native sulfur and copper, calcite, quartz, pyrite and galena. Learners are **not** expected to recall the chemical formula of other minerals.
(b)	rock-forming silicate minerals as crystalline materials built up from silicon–oxygen tetrahedra to form frameworks, sheets or chains and which may have a range of compositions (qualitative only)	To include: • silicon tetrahedra (olivine, garnet) • chains (pyroxene) • sheets (micas and clays) • frameworks (quartz, feldspar).
(c)	**(i)** the diagnostic physical properties of rock-forming minerals in hand specimens	To include: colour, lustre, shape, streak, cleavage/fracture, density, hardness, reaction with acid.
	(ii) the classification of samples, photographs and thin section diagrams of minerals using their diagnostic physical properties	To include the application of the diagnostic properties of the major rock-forming minerals.
	(iii) practical investigations to determine the density and hardness of mineral samples **(iv)** the techniques and procedures used to measure mass, length and volume.	To include: • Mohs hardness test • density test. *M1.1, M1.3, M1.4, M1.5, M1.6, M2.1, M3.2,* ***M4.1*** **PAG1** HSW4,5,8
(d)	the classification of rocks, which are made up of one or more minerals, as igneous, sedimentary or metamorphic using their relationship to temperatures and pressures in the rock cycle.	

2.1.2 Igneous rocks

Igneous rocks are the product of the cooling and solidification of magma or of lava.

Most igneous rocks can be classified based on their directly observable characteristics.

		Learning outcomes	Additional guidance
		Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	**(i)**	the classification of igneous rocks on the basis of their composition (silicic, intermediate, mafic and ultramafic) and crystal grain size (coarse-crystals >5 mm diameter; medium-crystals 1–5 mm diameter; fine-crystals <1 mm diameter)	To include: granite, microgranite, rhyolite; diorite, microdiorite, andesite; gabbro, dolerite, basalt and peridotite. *M1.2, M1.4, M1.5, M3.2* **PAG1** HSW8
	(ii)	the diagnostic properties of rocks to identify igneous rocks in samples, photographs and thin section diagrams	
(b)	**(i)**	igneous textures, crystal shape and crystal size as evidence for depth of formation and rate of cooling of igneous rocks	To include: volcanic and plutonic igneous rocks and obsidian.
	(ii)	the diagnostic properties of igneous textures and crystal shape in samples, photographs and thin section diagrams	To include: equicrystalline, glassy, vesicular, amygdaloidal, flow banding and porphyritic. *M1.4, M1.5, M3.2, M4.2* **PAG3** HSW1,8
	(iii)	the representation using drawings and annotated diagrams of igneous textures and crystal shape in samples	
	(iv)	the techniques and procedures used to measure temperature.	

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2.1.3 Sedimentary rocks

Sedimentary rocks are the product of physical, biological or chemical deposition.

Sedimentary rocks can be classified based on their directly observable characteristics.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	weathering and erosion, the mechanical, chemical and biological processes that produce the sediments that form sedimentary rocks	To include the formation of: • clastic material • clays • evaporites (gypsum, halite) • carbonate sediment. Learners should be able to recognise the mineral in a given chemical reaction but not recall the specific formula of individual minerals. HSW1
(b)	**(i)** the effect of the process of erosion on the characteristics and composition of modern sediments	To include: transport processes, Hjulström curve, length of transport and the concept of maturity.
	(ii) sieve analysis of sediments	*M1.2, M2.1, M2.4, M2.5, M2.6, **M2.7**, M2.8 **M2.12**, **M3.11*** **PAG4** HSW1
(c)	the diagnostic properties of rocks to recognise and measure grain sizes in samples, photographs and thin section diagrams	To include the phi scale (at AS, qualitative only). Recall of Folk and Ward formulae is **not** required. *M1.4, M1.5, M2.2, M2.5, M2.6, **M2.7**, M2.8, M3.2, **M3.4**, **M3.6*** **PAG1**
(d)	**(i)** the classification of siliciclastic rocks on the basis of their diagnostic properties (colour, composition, grain size and grain shape, sorting)	To include: orthoquartzite, arkose, greywacke.
	(ii) the classification of carbonate rocks on the basis of their diagnostic properties (grain size, cement, mineral composition and fossil content, and sorting)	To include the Dunham scheme (mudstone, wackestone, packstone, grainstone).
	(iii) the diagnostic properties of rocks to identify siliciclastic and carbonate rocks in samples, photographs and thin section diagrams	**PAG1**

	Learning outcomes		Additional guidance
(e)	the processes of diagenesis and lithification:		To include the effects of diagenesis on siliciclastic and carbonate grains, organic material and mud.
	(i)	mechanical compaction	
	(ii)	chemical compaction by pressure dissolution and recrystallisation	
	(iii)	growth of cements	To include: silica, calcite, hematite and clay minerals.
	(iv)	how these changes in rock texture modify the porosity and permeability of rocks.	Learners should be able to recognise the mineral in a given chemical reaction but not recall the specific formula of individual minerals. **PAG4** HSW1

2.1.4 Metamorphic rocks

Metamorphic rocks are the product of the readjustment of a sedimentary or igneous parent rock to different conditions of temperature and/or pressure.

The shale to gneiss series is used to illustrate the general principles of metamorphism.

Metamorphic rocks can be classified based on their directly observable characteristics.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	metamorphism as a solid state isochemical process that changes the characteristics of rock	To include: contact, dynamic and regional.
(b)	how the mineralogy and fabric of metamorphic rocks can be used to infer the composition of the parent rock	To include the formation of: • metaquartzite and marble • slate, phyllite, schist and gneiss from fine grained rocks. **PAG1** HSW1
(c)	how as the intensity of metamorphism changes different minerals form which can be used to reconstruct the conditions of metamorphism.	To include: metamorphic grade, index minerals. **PAG1** HSW1,2,8

2.2 Fossils and time

Fossils provide information about the interaction of organisms with the environment and an evolutionary record from which the geological timescale was developed. By combining biostratigraphy with numerical ages from radiometric dating of igneous rocks, the geological timescale allows geologists to reconstruct regional and global palaeoenvironments.

2.2.1 Fossils

This section introduces learners to fossils and the application of fossil data. These concepts will be further developed and applied in modules 4 and 7.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	fossils as the preserved remains of living organisms or the traces of those organisms	To include the preservation of body fossils by replacement and the formation of trace fossils (burrows, tracks and trails). **PAG5**
(b)	the nature and the reliability of the fossil record and the morphological definition of species	To include taphonomic processes which produce life and death assemblages, preservation potential. *M2.5, M2.6, M2.10,* ***M2.12*** HSW5,6,9,12
(c)	the use and interpretation of fossils as palaeoenvironmental indicators:	
	(i) trace fossils to provide information on the behaviour of the organism that formed them and the palaeoenvironment	To include: dwelling, protection and feeding structures and qualitative interpretation of locomotion.
	(ii) body fossils to provide information on the behaviour of the fossilised organism and the palaeoenvironment.	To include: skeleton thickness, robustness, ornament, sensory organs and geopetal structures within fossils. **PAG5** HSW1,5,9

2.2.2 Geological time

This section introduces the geological column and the principles used to construct it.

These concepts will be further developed and applied in module 7.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	**(i)** the use of radioactive decay rates of the radionuclides in minerals to give a numerical age of those minerals and rocks **(ii)** the plotting and interpretation of half-life curves	To include: qualitative historical consideration of other numerical dating methods for the age of the Earth, appropriate minerals, and the dating of sedimentary and metamorphic rocks. *M1.1, **M2.3**, M2.5, M2.9* HSW7,8,9,11
(b)	the geochronological division of the geological column for the Phanerozoic into eras and periods using a biostratigraphic relative time sequence.	To include basic identification of main invertebrate groups (trilobites, corals, brachiopods, bivalves, cephalopods) and an outline of the Palaeozoic, Mesozoic and Cenozoic faunas. **PAG5** Learners are **not** required to memorise dates.

Module 3: Global tectonics

When viewed on a geological timescale the Earth is the most dynamic of the terrestrial planets.

This section provides knowledge and understanding of the Earth, its structure and its place within the solar system. It builds on learners' knowledge of Earth science and places this within a scientific framework.

Learners will have knowledge of the geological phenomena from place-based study in geography, and relevant scientific principles from GCSE (9–1) Science.

This module aims to integrate learners' existing knowledge and extend their understanding of the interior of the Earth. It provides learners with the basis for understanding the tectonic environments in which rocks are formed and geological structures develop (3.1 Earth structure, 3.2 Plate tectonics and 3.3 Geological structures).

Learners are expected to apply knowledge, understanding and other skills developed in this module to new situations and/or to solve related problems.

3.1 Earth structure

Our understanding of the layered structure of the Earth has developed rapidly since the 1960s and benefited from Cold War military research. More recently, insight from planetary science and oil exploration technology have allowed geologists to refine their understanding. This is still an area of active research and many questions remain to be answered.

In presenting the geochemical and geophysical understanding of the structure of the Earth in separate subsections we aim to avoid the common misconception that assumes the crust and the lithosphere are synonymous and that the Moho discontinuity is the base of the lithosphere.

3.1.1 The physical structure of the Earth

This section looks at the geophysical structure of the Earth. Learners will be familiar with ideas of the properties of matter, waves, gravity and magnetism from GCSE (9–1) Physics and Chemistry.

These concepts will be further developed and applied in module 5.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	the layered structures of the Earth as defined by the rheological properties of the layers	To include how each layer deforms in response to an applied force.

	Learning outcomes	Additional guidance
(b)	how the variation in P and S wave velocities provides indirect evidence to identify layers within the Earth and how their paths through the Earth produces the P wave and S wave shadow zones	To include how the state and depth of the inner and outer core of the Earth can be determined. ***M2.4*** HSW3,5
(c)	the lithosphere as a rigid, brittle layer made of the crust and part of the upper mantle, which is divided into plates	
(d)	how evidence from gravity anomalies and isostasy provides indirect evidence to determine the behaviour of the lithosphere and asthenosphere	To include: gravity anomalies (free air and Bouguer), isostatic equilibrium and isostatic rebound. HSW1,2,3,5,7
(e)	how indirect evidence from electromagnetic (EM) surveys may be used to identify the lithosphere and asthenosphere at mid-ocean ridges	To include the relationship between conductivity and partial melting. HSW1,2,3,7
(f)	the nature of the asthenosphere as a rheid, plastic layer with 1–5% partial melting	To include the role of the asthenosphere in plate tectonics.
(g)	how the density of the whole Earth and the rocks at the surface provide indirect evidence to infer the density of the core and mantle rocks	***M4.1***
(h)	the probable geodynamo origin of the Earth's magnetic field which provides indirect evidence for the subdivision of the core.	To include convection in a rotating conducting fluid. HSW1,2,7

3.1.2 The origin of the Earth's structure

This section introduces the geochemistry and origin of the structure of the Earth. Learners will be familiar with ideas of energy transfer and states of substance from GCSE (9–1) Physics and Chemistry.

It is also an opportunity for learners to study both renewable geological resources (such as geothermal energy) and finite mineral resources and the need to manage these resources for long term sustainability.

The Goldschmidt classification of elements provides a framework for understanding the geochemical behaviour of elements which will be developed in module 5.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	the bulk composition of the Earth and how it is inferred from the composition of meteorites (chondrites) and the Sun	To include the use of normalised diagrams displaying element concentrations (qualitative only).
(b)	a qualitative explanation of the nebular hypothesis for the formation of the solar system and the Earth	To include the evidence for protoplanetary discs, and impact craters on the Earth and other bodies in the solar system. **PAG12** HSW1
(c)	the transfer of geothermal energy from: **(i)** heat of formation by the Earth **(ii)** radioactive decay within the Earth	To include: • transfer of thermal energy from differentiation (potential energy) • formation of the solid core (specific latent heat) • early bombardment (kinetic energy) • the radioactive decay of K, U and Th.
(d)	the Goldschmidt classification of elements into four groups and a qualitative understanding of the preferred formation of states of substances (oxides and sulfides)	Lithophile, siderophile, chalcophile, atmophile. Learners are **not** required to study enthalpy changes or free energy.
(e)	the differentiation of the Earth into layers of distinct composition and density by the partitioning of each of the Goldschmit groups between the crust, mantle, core, and atmosphere and hydrosphere	To include: evidence for meteorites as a possible source of rare siderophiles in the crust, crustal abundance and concentration factor. *M1.1, M1.4, M1.6, M3.2*
(f)	the geochemical layered structure of the Earth as defined by the mineral composition of the layers and how the composition of these layers is inferred from direct evidence.	To include evidence from rocks and seismology: deep mines and boreholes, ophiolites, kimberlite pipes, mantle xenoliths, and the Lehmann, Gutenberg and Moho discontinuities. HSW5

3.2 Plate tectonics

Of the terrestrial planets the Earth is the only one where geothermal energy is dissipated through plate tectonics. The plate tectonic paradigm allows geologists to explain the dissipation of heat by the Earth, tectonic environments, earthquakes and styles of igneous activity. On a longer timescale, the plate tectonics paradigm explains patterns of global sedimentation, long term sea level change and ore forming processes, as will be explored in modules 5 and 7.

3.2.1 The plate tectonics paradigm

Plate tectonics is a thermodynamically driven process which involves the mantle and the lithosphere.

The evidence for a dynamic Earth builds on a range of evidence from direct observation and remote sensing.

		Learning outcomes	Additional guidance
		Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)		the transfer of energy from within the Earth which drives the Earth's internal geological processes	To include: evidence for the geothermal gradient, convection, conduction and advection, and estimates of geothermal flux. *M3.2, M3.10*
(b)	**(i)**	the evidence from earthquake seismology data for the nature of lithospheric plates (aseismic interiors and boundaries defined by seismic activity)	To include earthquake foci along the inclined plane of a Benioff zone.
	(ii)	the evidence for structure in the mantle from seismic tomography data	To include subducted slabs and areas of upwelling.
	(iii)	the interpretation and analysis of seismograms	To include: • deriving the distance from epicentre; using time–distance curves to find the epicentre of an earthquake • use of seismograms to demonstrate shadow zones. *M3.7* **PAG2** HSW1,3,5,6,9,12
(c)		the nature of lithospheric plates: aseismic interiors and boundaries defined by seismic activity	

	Learning outcomes	Additional guidance
(d)	how the global distribution of geological features of the same age provides evidence to reconstruct historical plate movement	To include: orogenic belts (Caledonian orogeny–Iapetus), palaeoenvironments and geomagnetics (polar wandering curves), ocean floor magnetic anomalies, volcanic zones, palaeoecology and glacial geology. HSW1,5,6
(e)	the evidence for mantle plumes	To include: relative plate motion, geological features, heat flow and seismic tomography. HSW1,5,6
(f)	how the resolution and precision of the direct measurement of relative movement of points on different plates using global positioning systems (GPS) allow accurate measurement of the current relative movement of lithospheric plates	To include basic understanding of geodesy (ellipsoid model of the Earth, the geoid and terrestrial reference frames). Learners are **not** required to have an understanding of the operation of global positions systems. *M1.3* HSW1,3,5,6
(g)	subduction zones, lithospheric plates (cold thermal boundary) and mantle plumes which act as the active limbs of the convection cells which transfer energy from within the Earth	*M2.10*
(h)	how gravity and differences in density result in ridge push at mid-ocean ridges	To include passive upwelling at divergent plate boundaries and seafloor spreading.
(i)	the relative importance of slab pull at subduction zones and ridge push at mid-ocean ridges as mechanisms driving the movement of tectonic plates	
(j)	**(i)** how the plate tectonic paradigm emerged from previous, gradually more sophisticated models (geosynclines, continental drift, active mantle convection carrying passive tectonic plates)	To include: • evidence for and against Contraction theory • evidence from ocean basin research • continental blocks, isostasy, radioactivity and tectonic plates.
	(ii) interpretation of these and other examples of such developing models.	Learners are **not** expected to recall named scientists and specific dates. HSW7

3.2.2 Plate boundaries and igneous process

This section develops ideas of pressure and pressure differences in fluids, and chemical bonds which will be familiar to learners from GCSE (9–1) Physics and Chemistry.

Using buoyancy and changing physical properties provides a scientific framework for learners to understand igneous processes which will be developed in module 5.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	the generation of mafic magma by partial melting which results from upwelling of the mantle at divergent plate boundaries and intraplate hot spot settings	To include: geotherm, solidus, liquidus and adiabatic conditions.
(b)	the generation of intermediate and silicic magmas at convergent plate boundaries where crustal material is carried downward resulting in partial melting	To include magma mixing.
(c)	the processes of intrusion which cause a body of magma to ascend through the crust and how these affect the country rock	To include formation of diapirs and transgressive sills. ***M4.1***
(d)	**(i)** the characteristics of major and minor intrusive bodies and the settings under which they form	To include: chilled and baked margins and metamorphic aureoles.
	(ii) the use of geodetic and geophysical data to identify the subsurface intrusion of magma	To include: harmonic tremor, 3D visualisation of seismic data, tiltmeter and GPS observations. *M3.2, M3.7, M3.8* **PAG2** HSW3
(e)	**(i)** how changes in the properties of magma can affect buoyancy forces such that the magma can make its way to the surface producing a volcanic eruption	To include: exsolution of volatiles, crystal content, recharge and groundwater changes. **PAG3** HSW1,4
	(ii) practical investigations to model the properties of magma and how changes to conditions can affect buoyancy forces	
(f)	the diagnostic geological characteristics of dykes, sills and lava flows	

	Learning outcomes	Additional guidance
(g)	how the composition (percentage silica) and temperature of the erupting lava controls its viscosity and its ability to exsolve volatiles	To include a qualitative understanding of the effect of OH^- ions on silicate polymerisation. *M1.4, M3.2*
(h)	how the composition and physical characteristics of the erupted material control the volcanic landforms produced by both explosive and effusive activity	To include: • viscosity, rate of extrusion, gas content and frequency of eruption • fissure and central eruptions • subaerial and submarine • plateau, shield, composite and caldera
(i)	the nature of volcanic hazards and their relation to the composition and properties of the source magma.	To include the plotting and interpretation of isopachyte maps. *M3.7, M4.2* HSW8,9,12

3.3 Geological structures

This section introduces learners to structural geology and provides knowledge and understanding of folding, faulting and the behaviour of deforming rocks.

Learners are introduced to rock deformation at outcrop before considering regional and global tectonic environments.

3.3.1 Rock mechanics

This section introduces how rocks behave when subjected to stress. These concepts will be developed in module 6.

There are opportunities for learners to develop and apply these ideas in the laboratory and through fieldwork.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	**(i)** the geological structures produced by rock deformation as a result of tectonic stresses (tension, compression and shear forces) **(ii)** the identification, measurement and description of these geological structures on photographs, maps, cross-sections and in the field, including production of labelled field sketches **(iii)** the construction of geological cross-sections from geological maps **(iv)** use of a compass-clinometer	To include: • bedding planes: strike, dip and apparent dip, true thickness and apparent thickness • faults: fault plane, throw, fault dip, dip-slip, strike-slip, hanging wall, footwall, upthrow and downthrow • folds: fold limbs, symmetrical, asymmetrical, hinge, crest, trough, axial plane, axial plane trace, plunge, antiform and synform. • principal stresses. *M1.1, M1.4, M1.5,* ***M2.11****, M3.2, M4.2,* ***M4.3*** **PAG6** HSW4,5,8,10

	Learning outcomes	Additional guidance
(b)	**(i)** how tectonic stress and strain vary due to temperature, confining pressure and time, resulting in the plastic or brittle deformation of rocks	To include the formation of joints, slickensides and fault breccia. **PAG9** HSW8
	(ii) the use of stress and strain diagrams	*M3.7, M3.8*
(c)	how compressive forces can lead to the formation of a slaty cleavage.	To include the relationship of cleavage to folds.

3.3.2 Structural geology and plate boundaries

The plate tectonic paradigm provides a framework to understand both the distribution and styles of tectonic environments.

Knowledge of earthquakes and tectonic environment prepares learners for the study of module 6.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	how earthquakes occur when elastic strain energy stored in rocks is released (elastic rebound theory)	
(b)	how plate movement at transform boundaries causes shear dominated tectonic environments, which can lead to rock deformation as a result of tectonic induced stresses	To include stress transfer.
(c)	how plate movement at convergent boundaries causes compressive and shear dominated tectonic environments, which can lead to rock deformation as a result of tectonic or gravity induced stresses	To include: fold mountains, overfolds, isoclinal folds, nappes, thrusts. **PAG7**
(d)	how plate movement at divergent boundaries causes tensional dominated tectonic environments, which can lead to rock deformation as a result of tectonic or gravity induced stresses.	To include: graben (rift), horst, relationship between spreading rate and topography, and oceanic core complexes. *M3.10*

Module 4: Interpreting the past

The realisation by geologists that the Earth was the product of processes that could be studied and understood revolutionised science (uniformity of process).

This section provides knowledge and understanding of modern sediments and sedimentary rocks. It demonstrates the power of applying scientific theories and a systems approach to understanding a complex world.

Learners will have knowledge of rocks and the rock cycle from Key Stage 3 geography and science, and those who have studied GCSE (9–1) Geography will have knowledge of surface process. This section aims to build on learners' hands-on experience of rocks and fossils and demonstrate to them that the present is the key to the past.

Learners should gain knowledge and understanding of the relationship between sedimentary rocks and environments (4.1 Sedimentary environments in time, 4.2 Geochronology).

Learners are expected to apply knowledge, understanding and other skills developed in this module to new situations and/or to solve related problems.

4.1 Sedimentary environments in time

'The present is the key to the past.' – Charles Lyell, 1833

The discovery of the rock cycle and the principle of uniformitarianism by James Hutton demonstrated the importance of reviewing theory in the light of fieldwork.

The facies approach to sedimentary geology developed in the 1970s and is analogous to a niche in ecology. By viewing multiple characteristics of three-dimensional bodies, facies link modern environments with ancient rocks and avoid the limitations of the layer-cake approach.

Knowledge of the application of uniformitarianism to the understanding of sedimentary facies prepares learners for the study of modules 5 and 7.

4.1.1 Uniformitarianism and the rock cycle

The rock cycle and uniformitarianism were revolutionary ideas 200 years ago. Deep time was the catalyst to new ideas in other sciences and made geology the lead science of its day.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	the use of evidence in the field, photographs, diagrams and maps to recognise the rock cycle	To include the origin of an angular unconformity. **PAG6** HSW4,5,10

	Learning outcomes	Additional guidance
(b)	how uniformitarianism and the rock cycle model developed over time, including ideas of catastrophism, mass extinctions, and changing conditions and rates of processes through geological time including the contributions of James Hutton and William Smith	To include gradualism. HSW7,11
(c)	what facies associations are, why facies are the basic unit of sedimentary geology and how uniformitarianism is applied to the study of facies by analogy with modern sedimentary sequences and processes.	

4.1.2 Surface processes and products

This section develops and extends ideas of surface processes ('geomorphic processes') which will be familiar to learners from GCSE (9–1) Geography.

It focuses on facies and a systems approach to understanding sedimentary environments by applying the concept of uniformity of process.

		Learning outcomes	Additional guidance
		Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	**(i)**	how the characteristics of the facies in a sedimentary environment are related to the methods of sediment transport	To include the characteristics of sediments transported by wind, glaciers, rivers and in shallow marine environments.
	(ii)	the diagnostic sedimentary structures produced by the sediment transport processes	To include: cross-bedding, ripple marks, graded bedding, desiccation cracks, salt pseudomorphs and imbricate structure.
	(iii)	the recognition, application and sketching of the diagnostic properties of sedimentary structures to interpret way-up and sedimentary environments, in the field and on photographs	*M1.4, M1.5,* ***M2.6, M2.11, M2.12****, M4.2* **PAG4, PAG6** HSW1,4,5,10
(b)		the construction and interpretation of graphic logs of modern sediment sequences and ancient sedimentary rock	To include fossil assemblages, sedimentary structures and directional data. ***M2.6****, M4.2* **PAG6** HSW8, 10
(c)		deposition in fluvial environments which produces a characteristic three-dimensional architecture due to lateral migration	To include: meandering rivers, braided rivers and alluvial fans (channel sandstones, flood plain clays and silts, breccias, and conglomerates). *M2.8,* ***M2.11***

	Learning outcomes	Additional guidance
(d)	deposition in hot desert environments which are controlled by gradual aeolian processes and episodic high energy events	To include wadis, dunes and playa lakes (aeolian sandstones, evaporites). ***M2.6, M2.11***
(e)	deposition in shallow siliciclastic seas which produces characteristic offshore transitions from beach deposits, current reworked sand sheets to muds, below the wave base	***M2.6, M2.11***
(f)	deposition in shallow carbonate seas which produces characteristic limestones within, on and outside the reef (reef limestone, bioclastic limestone and oolitic limestones)	
(g)	deposition in deep water carbonate seas above the carbonate compensation depth.	To include chalk, micritic limestones and a qualitative understanding of chert/flint formation in siliciclastic starved seas and continental slopes.

4.2 Geochronology

'...we find no vestige of a beginning, – no prospect of an end.' – James Hutton, 1795

Hutton based his assertion on the field evidence for multiple rock cycles that he and his correspondents observed. Subsequent generations of geologists have developed increasingly sophisticated numerical dating techniques although reference to the most recent ICS chronostratigraphic chart will show that this is still a work in progress.

Knowledge of geochronology prepares learners for the study of modules 5 to 7.

4.2.1 Relative dating and biostratigraphy

This section introduces the geochronological principles of correlation (based on lithology and macrofossils) and relative dating.

There are opportunities for learners to develop and apply these ideas in the laboratory and through fieldwork.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	the geochronological principles used to place geological events in relative time sequences in outcrops, photographs, maps and cross-sections to interpret geological histories	To include: superposition, original horizontality, way-up criteria, cross-cutting relationships, included fragments and unconformities. *M1.4, M1.5, M4.2* **PAG6** HSW1, 10

	Learning outcomes	Additional guidance
(b)	the critical application of lithostratigraphic correlation (lateral variation, diachronous beds)	To include sequences of beds, thickness and composition. ***M4.3***
(c)	the application and limitations of relative dating	HSW6
(d)	biostratigraphic correlation using first appearance of macro fossils, stratigraphic range, extinction and fossil assemblages.	To include zone fossils. *M2.2*

Module 5: Petrology and economic geology

The most important applications of geology for the economy and society often come from discoveries made by academic scientists studying pure geology.

The aim of this module is to build on and extend the knowledge and understanding from modules 2, 3 and 4. This module covers advanced sedimentary, igneous and metamorphic processes, hydrogeology, and the formation and extraction of metallic mineral resources.

Where examples are given they are not exhaustive and other examples pertinent to the domain may be used (5.1 Applied sedimentology, 5.2 Fluids and geological processes, 5.3 Igneous petrology, 5.4 Metamorphic petrology and 5.5 Mining geology).

Learners are expected to apply knowledge, understanding and other skills developed in this module to new situations and/or to solve related problems.

5.1 Applied sedimentology

'…it is a basic statement of far reaching significance that only those facies … can be superimposed primarily which can be observed beside each other at the present time.' – Johannes Walther, 1894

Deltas and turbidites are examples of sedimentary environments where remote sensing and laboratory studies have been used to advance our understanding. Banded iron-formations are our most important source of iron ore but have no modern analogue.

Knowledge of sedimentary processes prepares learners for the study of module 7.

5.1.1 Sedimentary processes and resources

This section introduces turbidites and delta sequences as examples of complex sedimentary environments which can be understood using scientific models. They are also important rocks in hydrocarbon basins where Walther's law can be applied as a predictive tool.

Banded iron-formations are an example of an important economic resource deposited by sedimentary processes that no longer operate because of changes in the chemistry of the atmosphere and oceans.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	**(i)** the sedimentary processes which are infrequent and/or difficult to observe but can be understood and explained using scientific principles	To include: • Stokes' law: $v = \frac{gd^2(\rho_p - \rho_w)}{18\eta}$ (recall **not** required) • relationship between bedforms, flow velocity and grain size (flume studies) • flocculation of clay particles

	Learning outcomes	Additional guidance
		• use of the phi scale, including recall and use of $\varphi = -\log_2\left(\frac{D}{D_0}\right)$
	(ii) practical investigations to model the processes of sedimentation	To include formation of graded bedding, ripples and delta mouth switching. *M2.8, M3.2,* ***M3.3, M3.4, M3.6*** **PAG4** HSW1,2,4
(b)	turbidity currents and how the Bouma turbidite model of deposition demonstrates the application of sedimentary principles	To include: sole structures, flute casts, tool marks, rip up clasts, climbing ripples, laminations and rates of deposition of turbidites and calcareous and siliceous oozes. *M1.1,* ***M3.9*** HSW1
(c)	how simple (topset, foreset and bottom set) and more complex deltaic cyclothem models demonstrate the application of sedimentary principles	To include: delta top (peat/coal, seat earth and channel sandstone), mouth bars and delta front and prodelta. HSW1
(d)	Walther's law which relates vertical sequences in outcrop with the lateral facies changes seen in modern environments	To include: comparison of Carboniferous delta sequences with modern deltas. HSW1
(e)	the deposition of banded iron-formations (BIFs) under the different atmospheric and ocean chemistry in the Palaeoproterozoic, as an example of a geological resource produced by sedimentary processes.	To include: the importance of BIFs deposits, photoferrotrophs, great oxidation event (GOE), oxidation of Fe^{2+} to Fe^{3+}. Learners are **not** expected to know detail of redox potential or electron donation. Learners should be able to recognise the mineral from its chemical formula but not recall the specific formula of individual minerals. HSW1 **See also 5.5.1(a)**

5.2 Fluids and geological processes

This section will focus on the geological factors that control the movement and storage of groundwater.

Darcy's law will be used as a tool to model the flow of fluids in rocks.

2

5.2.1 Fluids in rocks

The ideas developed here in the context of groundwater and connate fluids will be extended throughout modules 5 to 7 to other fluids, sources of pollution, and geological processes.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	**(i)** how porosity controls the storage of fluids (water, oil and gas) in rocks	To include: depth, temperature, primary and secondary porosity.
	(ii) how permeability controls the movement of fluids through rocks	To include the effects of diagenesis, fracturing and capillary pressure (oil and water). **PAG8**
(b)	the application of Darcy's law to model the flow of fluids in rocks $Q = -\kappa A\left(\frac{h_2 - h_1}{L}\right)$	To include: hydrostatic pressure and hydraulic gradient. Learners should be able to recall the expression for the hydraulic gradient, but will **not** be asked to recall Darcy's law. *M1.1, M1.3, M3.2,* ***M3.3, M3.4*** HSW1
(c)	the controls on groundwater quality which result from geochemistry (carbonates and sulfates), aquifer filtration and residence time	To include connate fluids in sedimentary basins. Learners should be able to recognise the mineral from its chemical formula but not recall the specific formula of individual minerals. HSW9
(d)	the characteristics of subsurface geology which control the flow of groundwater (hydrogeology) including confined and unconfined aquifers, aquicludes, aquitards, the water table, piezometric surfaces and recharge zones.	To include formation of springs (water) and seeps (hydrocarbons). **PAG8** HSW1

5.3 Igneous petrology

Igneous petrology (5.3.1) develops ideas introduced in module 3 to the evolution of magmas and formation of layered igneous intrusions.

Mid-ocean ridges (5.3.2) brings together ideas from modules 2 and 3 and applies them to the largest global igneous system.

5.3.1 Igneous petrology

This section extends knowledge of silicate mineralogy to the substitution of elements within the crystal structure and an understanding of solid solution series.

Knowledge and understanding of igneous processes will focus on how magma composition evolves and is modified during crystallisation.

Binary phase diagrams will be used as a tool to model magma crystallisation.

		Learning outcomes	Additional guidance
		Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	**(i)**	the substitution of elements for others in the crystal structure of minerals and as magma cools and crystallises (olivine and plagioclase feldspar as examples of solid solution series)	To include: Bowen's reaction series, mafic minerals (discontinuous reaction series) and plagioclase feldspars (continuous solid solution series), zoned crystals.
	(ii)	the interpretation of continuous and discontinuous binary phase diagrams	To include: anorthite–albite, forsterite–fayalite and diopside–anorthite systems. **PAG3** HSW5
(b)		the geological processes (assimilation, differentiation and fractionation) which cause magma composition to evolve and be modified	To include: magma mixing, fractional crystallisation, gravity settling and filter pressing. ***M4.1***
(c)		the formation of layered intrusions and metal ores by magmatic differentiation, as an example of a geological resource produced by igneous processes.	To include chalcophile cumulates and platinum group elements (PGE). **PAG7** **See also 5.5.1(a)**

5.3.2 Mid-ocean ridges

'I think our maps contributed to a revolution in geological thinking, which in some ways compares to the Copernican revolution. … You could see the worldwide mid-ocean ridge and you could see that it coincided with earthquakes. The borders of the plates took shape, leading rapidly to the more comprehensive theory of plate tectonics.'
– Marie Tharp, 1999

Mid-ocean ridges are a major area of current research which has transformed our understanding of them, but for which there are still many outstanding issues.

Advection at mid-ocean ridges results in metasomatism which deposits significant metal ores.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	**(i)** the relationship between spreading rate and seabed morphology (water depth, fast and slow spreading mid-ocean ridges)	To include the calculation of seafloor spreading rates from different data sources.
	(ii) the calculation of numerical age using radioactive decay rates	Recall of the equation $N = N_0 e^{-\lambda t}$ is **not** required. *M1.4, M1.5, M2.10, M3.2,* ***M3.3, M3.4, M3.5****,* ***M3.6****,* ***M3.11*** HSW2,5
(b)	the evidence for the internal structure and processes at mid-ocean ridges (ophiolite complexes and geophysical surveys: gravity, reflection seismic and geoelectrical)	To include: free air and Bouguer anomalies, and electromagnetic (EM) surveys. **PAG12** HSW5,6
(c)	the formation of oceanic crust, how mid-ocean ridges are formed, and the process of seafloor spreading at fast and slow spreading mid-ocean ridges	To include: adiabatic melting of the mantle, magma evolution, mush zones, continuous and discontinuous magma chambers. *M3.7* HSW5
(d)	hydrothermal processes at mid-ocean ridges and the formation of massive sulfide metal ores as an example of a geological resource produced by hydrothermal processes.	To include metasomatism and chalcophiles. **PAG8** **See also 5.5.1(a)**

5.4 Metamorphic petrology

'the considerations which have been advanced … suggest that these special features may after all be due to the depth in the Earth's crust at which the metamorphism took place, rather than to any physical conditions peculiar to early geological time.' – George Barrow, 1893

The mineralogy and fabric of regionally metamorphosed rocks (and particularly pelitic rocks) can be interpreted by geologists to reveal the nature of the original sedimentary or igneous parent rock and their history of burial, deformation and exhumation.

5.4.1 Metamorphic petrology

This section introduces the regional metamorphism and the use of pressure–temperature diagrams to reconstruct conditions of metamorphism.

There are opportunities for learners to develop and apply these ideas through fieldwork.

		Learning outcomes	Additional guidance
		Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	**(i)**	metamorphic grade and how the formation of different combinations of minerals can be used to reconstruct the conditions of metamorphism and infer the composition of the parent rock	To include: metamorphic facies, stability fields, index minerals (chlorite, biotite, garnet, kyanite and sillimanite), Al_2SiO_5 polymorphs and retrograde metamorphism.
	(ii)	the plotting and interpretation of isograds to reconstruct conditions of metamorphism	*M1.2, M3.7* **PAG7** HSW1,5,8
(b)	**(i)**	the formation of metamorphic fabrics as a result of directed stress and time during mountain building (orogeny) and the use of fabrics to reconstruct conditions of metamorphism	To include: slaty cleavage, schistosity, gneissose banding, porphyroblastic and granoblastic fabrics and crenulation cleavage. **PAG3, PAG7** HSW5
	(ii)	the diagnostic properties of metamorphic fabrics in samples, photographs and thin section diagrams	
(c)		how the composition of the parent rock and conditions (strain rate, temperature and pressure) at the time of rock deformation determine the nature of that rock deformation.	To include: competent and incompetent rocks, fracture vs folding, shortening (slip, buckling, pressure solution), boudinage and refolding. **PAG7**

5.5 Mining geology

'Locating and extracting geological resources are vital to the UK's GDP, tax revenues and economic growth. The use of raw materials for industrial and consumer products and processes, and of fossil fuels for energy, underpin our prosperity and are major contributors to the economy in their own right. The extraction of oil, gas, coal and construction and industrial minerals in the UK generated £38bn in 2011 – about 12% of non-service GDP – with the industries dependent on these resources contributing even more.' – Geology for Society, GSL, 2014

5.5.1 Exploration for metals

This section introduces ideas of resources, reserves and examples of the geochemical and physical processes that concentrate ores. There are opportunities for learners to develop and apply these ideas through laboratory and fieldwork.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	the low crustal abundances of metals and the concentration factors that produce economic ore deposits	To include: resource, reserve, ore mineral, gangue mineral, average crustal abundance, cut-off grade and concentration factor. *M1.1, M1.4, M1.6, M3.2,* ***M4.1*** **PAG10**
(b)	the concentration of copper ore minerals by the processes of secondary enrichment as a result of chemical weathering and chemical reactions above and below the water table	To include chalcopyrite. Learners should be able to recognise the mineral from its chemical formula but not recall the specific formula of individual minerals.
(c)	the concentration of ore in placer deposits in rivers and on beaches	To include the properties of ores (cassiterite, gold and diamonds) that favour concentration in placers. **PAG10**
(d)	geophysical exploration techniques used to find metals	To include: magnetic, gravity and electromagnetic (EM) surveys. **PAG10** HSW5
(e)	geochemical exploration methods used to find metals	To include analysis of: stream sediment, soil, water and vegetation samples. **PAG10** HSW5 Learners should be able to recognise the mineral from its chemical formula but not recall the specific formula of individual minerals.

	Learning outcomes	Additional guidance
(f)	how existing data sets and follow-up surveys are integrated in geological prospecting, resource exploration and in defining the reserves.	To include: • target selection • exploration drilling • estimation of reserve size • limitations in the accurate determination of reserves. *M1.6*, ***M4.1*** HSW1,2,3,5,6

5.5.2 Resource extraction and impacts

This section introduces ideas of resource extraction, management and abandonment. Former mining operations are considered both for their reuse and mitigation of impact.

There are opportunities for learners to develop and apply these ideas through laboratory and fieldwork.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	the principles, economics and sustainability of surface and underground mining operations	To include: open pit, stope and longwall retreat techniques, phased development and life cycle of a mining development. HSW9
(b)	the principles, economics and sustainability of mineral processing operations	To include: *in situ* and heap leaching, crushing and tailings disposal, froth floatation and smelting. HSW9
(c)	the causes and management of contaminated minewater, a source of pollution, from abandoned coal mines and metal ore mines	To include: • the geochemistry of minewater (acidity and dissolved metals) • passive and active treatment • barriers and dewatering. ***M4.1*** **PAG12** HSW9,10,12
(d)	the geological controls on the use of former underground resource operations as repositories for the storage of waste products.	To include radioactive waste and carbon dioxide. **PAG12** HSW2,9,10,11,12

Module 6: Geohazards

Geohazards are natural geological processes that impact adversely on people and the built environment. While spectacular low frequency high magnitude 'natural disasters', such as earthquakes, catch the news, low magnitude high frequency processes such as swelling clays or groundwater geochemistry can have as high an impact on people and structures.

The aims of this module are to provide understanding of how geological knowledge can save lives and money.

The two sections (6.1 Geohazards and 6.2 Engineering geology) investigate potential hazards from the natural world and the built environment that can be mitigated by geological expertise.

The natural world involves many variables and does not usually provide reliable prediction of catastrophic events, yet careful application of the science can give a forecast probability which should benefit planning and preparation.

6.1 Geohazards

Using earthquakes as an example of a complex geohazard, the generation and propagation of seismic energy is reviewed along with some of the factors that control earthquake impacts on humanity.

The difficulties of prediction are considered and compared with those involved in predicting volcanic eruptions. The less spectacular and more relevant hazards experienced in the UK are considered.

6.1.1 Earthquake geology

Impact factors can be divided into geological (which requires understanding of how seismic waves are generated and propagated) and the interaction of seismic waves with the built environment.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	the factors which affect the impact of earthquakes	To include: • the absorption and attenuation of energy as seismic waves travel through the Earth • Moment magnitude, including use of given equations e.g. $M_w = {}^2/_3 \log E - 6.1$ • the Mercalli intensity scale. *M3.2*, ***M3.3***, ***M3.4***, ***M3.5***, ***M3.6*** HSW2,12
(b)	**(i)** the interaction of the transmission of seismic energy and the competence of the bedrock/soil	To include the effect of velocity change on amplitude. **PAG2**
	(ii) the interaction of groundwater with seismic waves (liquefaction)	

	Learning outcomes	Additional guidance
(c)	how civil engineering can reduce the impact of future seismic events	To include the natural frequency of structures. HSW9,12
(d)	the limitations and utility of seismic hazard risk analysis which synthesise and summarise geological data sets to communicate this information for the use of non-specialists.	To include: the role of geologists in the framing of building construction codes, disaster planning, public education and communication on earthquake impacts HSW2,5,6,7,8,9,10,11,12

6.1.2 Geohazard risk analysis

The impact of hazards can be reduced by acting on an analysis of the risks involved based on current understanding of the geological processes. This is illustrated by considering seismic risk analysis.

Learners should appreciate the difference between a probability forecast and a (deterministic) prediction.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	**(i)** the effectiveness and limitations of probabilistic forecasting	
	(ii) the calculation of probability and return periods from an annual maximum time series (of geological events)	To include recall of the equation return period = $\frac{n+1}{m}$ ***M2.3*** HSW3,5,6,8
	(iii) the appropriate communication of probability and return periods for the use of non-specialists	
(b)	the effectiveness and limitations of deterministic predictions of tectonic geohazards	To include: seismic gap theory, use of changes in ground conditions close to faults, microseismics as eruption predictors, and tsunami warning systems. HSW5,6
(c)	the use of geographical information systems (GIS) to synthesise and summarise geological and geographic data to improve disaster planning and communication of information for the use of non-specialists.	**PAG9** HSW3,5,6,8,9,12

6.1.3 Geohazards in the British Isles

Shrink–swell behaviour is the most damaging geohazard in the UK today, costing the economy an estimated £3 billion over the past 10 years (source: BGS).

These examples of geohazards form a basis for further studies but are important in these densely populated islands despite the intraplate setting.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	shrinking and swelling clays:	
	(i) the causes of physical and geochemical changes to these clays in excavations and the forces generated by the interaction of these clays with groundwater	To include: comparison of kaolinite and smectite, dewatering, oxidation, compaction.
	(ii) the effects of shrinking and swelling clays on structures and the application of engineering geology to mitigate these effects	Learners should be able to recognise the mineral from its chemical formula but not recall the specific formula of individual minerals. HSW5,9
(b)	the causes and effects of subsidence and the application of engineering geology to mitigate these effects	To include: shrinking and swelling clays, limestone (solution sinkholes) and mining subsidence. HSW1,9,12
(c)	the causes and effects of landslides and the application of engineering geology to mitigate these effects	To include: mechanisms, characteristics and controlling factors of slope failures in competent and incompetent rocks; slope stabilisation. **PAG9** HSW1,9,12
(d)	the geological evidence for significant tsunamis in the recent geological past, their causes and the risk of future events.	To include the Storegga Slide. HSW5

6.2 Engineering geology

Detailed geological mapping and laboratory tests on the strength of rock and soils are necessary before the design and construction of any major engineering project to ensure public safety.

6.2.1 Geotechnics

The strength of rock can be measured in different ways and will vary according to the rock type. These strengths will be reduced by weathering. However the weakness and possible failure of rock is largely determined by discontinuities within the rock.

		Learning outcomes	Additional guidance
		Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	**(i)**	the effect of the interlocking and cementation of component minerals on rock strength	To include strengths of typical igneous, metamorphic and sedimentary rocks.
	(ii)	the measurement of rock strength under compression and under shear	To include a qualitative understanding of peak strength and residual strength but knowledge of the Young modulus is **not** required.
	(iii)	the density of rocks	To include lithostatic pressure ($p = \rho gh$) and density of water; other calculations not required. *M1.1, M1.3, M2.9, M3.2,* ***M4.1*** **PAG9**
(b)		how the strength of rocks and sediments is changed by weathering, fracture density and geological structures	To include: bedding, joint sets, foliation and faulting.
(c)		how the strength of rocks and sediments is changed by hydrostatic pressure (pore water)	To include the resolution of forces. *M3.7, M4.2* **PAG8**
(d)		how existing data sets and ground investigations are integrated in a geotechnical site assessment.	To include: • existing BGS mapping • geological site mapping, drilling for core samples, laboratory testing of samples • use of slope mapping to contribute to slope stability risk analysis. *M2.1* **PAG12** HSW5,6,8,9,12

6.2.2 Applied engineering geology

The larger the project, the greater the chance of catastrophic failure if the geotechnical surveys are inadequate. This can often result in large financial losses; the worst cases have resulted in loss of lives.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	tunnelling as an example of a major civil engineering activity which impacts the natural and built environment:	To include an awareness of the importance of infrastructure projects involving tunnelling.
	(i) how engineering geology is applied to the construction of tunnels through both hard rock and unconsolidated material	
	(ii) the application of engineering geology to monitor and mitigate the impacts of tunnelling	To include the management and use of spoil. HSW9
(b)	dams as an example of a major civil engineering activity with multiple geological impacts on the natural environment:	To include the impacts of historical and new construction. HSW9
	(i) how engineering geology is applied to the construction of dams	To include: earth, gravity and arch dams, grouting; clay/geomembrane lining, cut-off curtain.
	(ii) the application of engineering geology to monitor and mitigate the hydrogeological impact of dams	To include: hydrostatic uplift, erosion of earth dams.
	(iii) the application of engineering geology to monitor and mitigate the impact of dams on slope stability	
	(iv) the application of engineering geology to monitor and mitigate the impact of dam-impounded reservoirs on seismic activity	To include the evidence for reservoir-induced seismicity.
(c)	the role of geological understanding in the management and remediation of contaminated land and groundwater, a source of pollution, such as former industrial brownfield sites.	To include the geochemistry of heavy metal contamination of soils (adsorption on clay minerals, solubility, bioavailability and pH) and organic (hydrocarbons and solvents) contamination of soils and groundwater. Remediation to include: • phytoremediation • stabilisation/solidification (s/s). Learners should be able to recognise the mineral from its chemical formula but not recall the specific formula of individual minerals. **PAG9** HSW9,10

Module 7: Basin analysis

Basin analysis is a geological multidisciplinary systems approach to the study of sedimentary basins. The focus may be on sedimentology, palaeontology and integrating fieldwork but knowledge and understanding of economic geology, geochemistry, geophysics, structural geology, hydrogeology and fluid flow will be referenced. There are also opportunities to study iconic fossil groups such as the Burgess Shale fauna and dinosaurs.

Synopticity is embedded within the study of geology, including basin analysis; when presented with a problem a geologist will call upon their full range of geological knowledge and understanding and their experience of rocks in the field.

The module builds on and extends the knowledge and understanding from modules 2, 3, 4 and 5. The two sections (7.1 Key concepts for basin analysis and 7.2 Basin analysis in practice) develop learners' understanding of how geological evidence can be used and then applies this understanding to a range of sedimentary basins including classic Lagerstätten and case studies from the British Isles that will be accessible to most learners.

The emphasis is on integrated study, each individual learning outcome is informed by the others within each section and across the module.

Learners are expected to apply knowledge, understanding and other skills developed in this module to new situations and/or to solve related problems.

7.1 Key concepts for basin analysis

Key concepts for basin analysis include: Earth changes – the Earth's climate and the positions of the continents change over geological time; applied palaeontology and evolution – focusing on the fossil groups encountered in the module 7.2 and mass extinctions – evidence for gradualism versus catastrophism and the importance of uniformity of processes.

7.1.1 The changing Earth

This section will extend knowledge of global changes and gives a flavour of the non-permanence of the Earth in terms of climate and the global position of the continents.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	how the Earth has changed through geological time (with particular focus on the Phanerozoic Eon):	To include the breakup of Pannotia, assembly and breakup of Pangaea.
	(i) the changes in the distribution of continents from the Neoproterozoic – refer to 3.2.1	
	(ii) the long term changes in the Earth's climate and composition of the atmosphere	To include icehouse–greenhouse cycles, and the role of volcanic activity in climate modification.
	(iii) the long term changes in global sea level	
	(iv) how the Wilson cycle model can provide an outline framework to understand these long term changes and the link to mass extinctions	**PAG12** HSW1
(b)	how the long term changes in 7.1.1(a) can be interpreted from both the geological record (palaeoenvironments) and the geochemistry of the rocks, including isotope studies	To include: • palaeontological evidence (corals and plants) • lithological evidence (coal, desert sandstones, evaporites, tillites and reef limestones) • the use of oxygen (^{18}O and ^{16}O) and carbon (^{13}C and ^{12}C) isotopes • eustatic sea level changes and Vail sea level curves. ***M2.12*** HSW5
(c)	how the current rate and scale of environmental and biological change illustrate the application of geochronological principles, and are of the same order as those used to divide the geological timescale.	To include the global impact of human activity on the planet in comparison with past geological change, as evidence for an Anthropocene epoch. HSW2,6,9,10,11,12

7.1.2 Evolution and applied palaeontology

This section develops ideas on the application of fossils for palaeoenvironmental analysis to specific fossil groups which will be used in module 7.2.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	how the evolution of life on Earth, displayed in the marine fossil record, is used as evidence to investigate long term gradual change	HSW5,6
	(i) the adaptation of the basic trilobite morphology to occupy multiple marine niches during the Palaeozoic	To include: benthonic epifaunal, benthonic infaunal, nektonic and planktonic.
	(ii) the application of the ecology of modern reef building (scleractinian) corals to interpret and compare fossil corals (tablulate, rugose) as palaeoenvironmental indicators of reef building in the geological record	To include the symbiotic relationships with algae.
	(iii) the adaptation of the basic brachiopod morphology to occupy high energy and low energy marine environments	To include cemented and non-cemented free-lying, pedically attached and brachiopod reef builders.
	(iv) the morphological similarities and differences between brachiopods and bivalves	**PAG5**
(b)	how the evolution of life on Earth, displayed in the terrestrial fossil record, is used as evidence to investigate long term gradual change	HSW5,6
	(i) how amphibians evolved from marine animals in the Devonian and were adapted to terrestrial life in the Carboniferous	To include the similarities between marine animals and the early amphibians in the Devonian using skull morphology, fin bones, limb bones, teeth, body shape, tail fin and scales.
	(ii) the characteristics of the amniotic egg and the evolutionary advantage it gave for the development of life on land	
	(iii) the adaptation of the basic dinosaur morphology to occupy different terrestrial niches as exemplified by saurischian (sauropoda, theropoda) and ornithichian dinosaurs	To include the characteristics of saurischian dinosaurs (sauropod herbivores and theropod carnivores) and ornithischian dinosaurs.
	(iv) how birds evolved from theropoda and the morphological similarities and differences between birds and pterosauria.	To include the function of feathers and convergent evolution. **PAG12**

7.1.3 Mass extinctions

Although in general Earth changes are incremental and gradual (gradualism) studies of the fossil record have identified periods when change was rapid and sudden even by non-geological timescales (catastrophism).

This section will extend knowledge of how the study of fossils can be integrated within a multi-disciplinary approach to understand the extent and causes of mass extinctions.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	how the fossil record provides evidence for a number of short term catastrophic events through geological time known as mass extinctions and their probable causes	To include: • Permo–Triassic boundary and the evidence that major volcanic activity (Siberian Traps) contributed to this mass extinction • Ordovician–Silurian boundary and the evidence that massive climate change and the elimination of habitats contributed to this mass extinction • Cretaceous–Tertiary boundary and the evidence that a major asteroid impact and volcanic activity (Deccan Traps) contributed to this mass extinction. HSW5,6
(b)	how mass extinctions resulted in the replacement of the dominant forms in major ecological habitats.	

7.2 Basin analysis in practice

This final part of the course allows learners to review their geological knowledge and apply their understanding synoptically to both classic Lagerstätten and accessible British sedimentary basins. Basin analysis involves application of the full range of geological study to unravelling the history and development of basins as 'geodynamic systems'.

Although it is not possible to simulate the full complexity to learners there are opportunities for enrichment, integrating fieldwork and self-directed study. The intention is to provide stimulating contexts and content to round out the course and prepare learners for the transition to Earth science studies at HE.

7.2.1 Lagerstätten deposits

Lagerstätten are basins (or parts of basins) where the particular conditions during deposition and/or early diagenesis provide exceptionally complete preservation of individual organisms or even complete ecosystems. Geologists can apply the understanding gained through the study of Lagerstätten to other basins.

This section uses analysis of two basins from the Cambrian and one contrasting basin from the Jurassic Period. The focus of this content is on the exceptional preservation and the palaeoenvironmental conditions that allowed these deposits to form.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	the geological settings and sedimentary conditions that led to the exceptional preservation of organisms in key Lagerstätten deposits from the Middle Cambrian Burgess Shale (Canada) and the Lower Cambrian Chengjiang Formation (China)	To include: • key rock types and sedimentary structures as evidence for rapid burial • how inferred conditions and early diagenesis affect the level of detail in the fossil record.
	(i) the mechanism of preservation of hard and soft tissues in these Lagerstätten deposits	
	(ii) how these Lagerstätten deposits provide the evidence for the Cambrian explosion	To include fossil assemblages from the Burgess Shale (Canada) and the Chengjiang Formation (China) to interpret the depositional palaeoenvironments. HSW5,6
(b)	the geological settings and sedimentary conditions that led to the exceptional preservation of organisms in the Jurassic Solnhofen Limestone (Germany)	To include changes of salinity in a shallow lagoon environment.
	(i) the preservation of feathers, hard and soft tissues in a range of organisms	
	(ii) the evidence for the evolution of *Archaeopteryx*.	To include the similarities of *Archaeopteryx* to both dinosaurs and birds. **PAG5** HSW6

7.2.2 Oil and gas basins

Oil and gas basins covers the formation, maturation, migration and trapping of oil and natural gas in the North Sea, as well as techniques which are used to locate hydrocarbon deposits.

This section will extend knowledge of oil and gas formation, maturation, migration and trapping.

It also covers alternative future exploration and extraction in the onshore basins.

There will be an opportunity for both two- and three-dimensional data in the form of graphic logs or geophysical data to be examined in the exploration for oil and gas.

		Learning outcomes	Additional guidance
		Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)		the principles of basin analysis as applied to the prospecting for hydrocarbons in the North Sea Basin:	**PAG10**
	(i)	the geological settings and sedimentary conditions that led to the formation of oil and natural gas in the North Sea Basin	To include burial history curves. *M2.9* *M3.10*
	(ii)	the palaeoenvironments where the source rocks, reservoir rocks and caprocks formed	
	(iii)	the process of maturation to form oil and natural gas in the source rock	
(b)	**(i)**	the process of migration of oil and natural gas (fluids) from a source rock to reservoir rock under a caprock and the factors that control migration	To include: porosity and permeability of reservoir rocks and suitable caprocks. **PAG8**
	(ii)	The process of rifting and synsedimentary faulting in the North Sea Basin which allowed oil and natural gas traps to form	To include: anticline, fault, salt dome, unconformity, lithological traps.
	(iii)	The accumulation of oil and gas in trap structures under caprocks	To include how oil and natural gas may be destroyed or lost from these trap structures.

		Learning outcomes	Additional guidance
(c)	**(i)**	geophysical exploration techniques to interpret the structural history of the basin and locate hydrocarbon reserves	To include: seismic reflection and gravity surveys.
	(ii)	exploration drilling and downhole logging techniques to locate hydrocarbon reserves and plan field development	To include: porosity, gamma ray and resistivity downhole logging techniques, primary and secondary recovery.
	(iii)	the use of microfossils in biostratigraphy and palaeoenvironmental analysis to locate hydrocarbon reserves	To include: foraminifera, coccolithophores and palynomorphs (pollen, spores and dinoflagellates). ***M4.1*** **PAG5, PAG10** HSW5,9,10,11,12
(d)		how the same principles of basin analysis can be applied to onshore hydrocarbon basins.	To include novel extraction techniques (directional drilling and fracking). **PAG12**

7.2.3 Whole basin facies analysis

'Basin analysis requires an understanding of many diverse geological specialities and an ability to assess the relationships between varied types of evidence ... [these skills] are demanded by the nature of the work performed by many professionals in the petroleum and mining industry and by those engaged in government surveys.' – Andrew Miall, 1990

This section will extend knowledge of facies analysis, by the full integration of sedimentary structures, sedimentary rocks and fossils found in two basins.

The focus is to apply full facies analysis, considering sedimentary structures, sediments and fossils in an integrated way.

The graphic log will be the main tool for the analysis of these different environments.

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	the principles of basin analysis to the integration of the sedimentology and palaeontology of the Welsh basin: **(i)** the geological settings and sedimentary conditions in the Welsh Basin, throughout the Cambrian, Ordovician and Silurian periods. **(ii)** how palaeoenvironments in the Welsh Basin can be determined by the analysis of facies (sediments and fossils)	To include: • deep sea turbidites and shelf deposition • reef limestones • use of: trilobites, corals and graptolites as zone fossils. **PAG4** HSW5
	(iii) the zonation of the Welsh Basin using zone fossils	To include: trilobites, corals and graptolites as zone fossils.
(b)	the principles of basin analysis in relation to the Jurassic rocks which crop out across the United Kingdom (in a local context): **(i)** the evidence for the geological setting and cyclical sedimentation in shallow seas **(ii)** facies analysis of the sediments formed in the basin (sedimentary structures, sediment type and fossils) to determine palaeoenvrionments **(iii)** the zonation and correlation of the Jurassic Period using ammonites and belemnites	To include: • the deposition of shales, limestones, siltstones, sandstones and ironstones • the use of burrows and other trace fossils to determine palaeoenvironments • key common macrofossils (ammonites, belemnites and bivalves) • marine reptiles (ichthyosaurs and plesiosaurs) and flying vertebrates (pterosaurs) • use of ammonites and belemnites in determining palaeoenvironments. **PAG4** HSW5
(c)	practical investigation integrating field geology and secondary data (e.g. geological maps, seismic data, well logs, fossils) to understand the palaeoenvironments and geological history within the context of a basin wide study.	*M2.5*, ***M2.6***, *M2.8*, ***M2.11*** **PAG12** HSW1,2,3,4,5,6,8

2d. Prior knowledge, learning and progression

This specification has been developed for learners who wish to continue with a study of geology at Level 3. The A Level specification has been written to provide progression from GCSE (9–1) Science qualifications, GCSE (9–1) Geology, GCSE Geology or from AS Level Geology. Learners who have successfully taken other Level 2 qualifications in Science with appropriate geology content may also have acquired sufficient knowledge and understanding to begin the A Level Geology course.

There is no formal requirement for prior knowledge of geology for entry onto this qualification. Other learners without formal qualifications may have acquired sufficient knowledge of geology to enable progression onto the course. Some learners may wish to follow a geology course for only one year as an AS, in order to broaden their curriculum, and to develop their interest and understanding of different areas of the subject. Others may follow a co-teachable route, completing the one-year AS course and/or then moving to the two-year A Level.

The A Level Geology course will prepare learners for progression to undergraduate study, enabling them to enter a range of academic and vocational careers in geosciences, civil engineering, seismology, hydrogeology, environmental science, planetary science, mineral surveying, geological engineering and geophysics. Learners will also acquire a range of transferable skills applicable to science careers more broadly and other careers that value numeracy, scientific method and data analysis skills. It also provides a strong background and progression pathway for learners wishing to follow an apprenticeship route or those seeking direct entry into science careers.

Find out more at www.ocr.org.uk

2e. Scientific literacy

Throughout the course, learners will be given opportunities to practise and demonstrate their scientific literacy skills. 'Scientific literacy' means the ability to comprehend a passage of text of A Level standard, to extract information from it and to use this information. Use of the information may take the form e.g. of a calculation or to construct an argument. Scientific literacy also involves being able to answer questions logically and with due regard for the correct use of technical terms.

Scientific literacy will be formally assessed across the three written components in the A Level assessment. Aspects of the assessment that relate to scientific literacy include:

- extended response items assessed through Level of Response mark schemes, which reward responses that are coherent, relevant, substantiated and logically structured, with the correct use of technical terms
- questions set in unfamiliar contexts
- questions assessing the comprehension of a longer passage of text
- questions assessing comprehension of and use of data.

Scientific literacy skills may be assessed within the context of any of the learning outcomes included in Section 2c, including in conjunction with assessment of any of the practical skills in module 1.

3 Assessment of OCR A Level in Geology

3a. Forms of assessment

The OCR A Level in Geology consists of three externally assessed written components (01–03) and one non-exam assessment, Practical Endorsement component (04).

All three externally assessed components contain some synoptic assessment (see Section 3f), some extended response questions (see Section 3e) and some stretch and challenge questions.

Stretch and challenge questions are designed to allow the most able learners the opportunity to demonstrate the full extent of their knowledge and skills.

Stretch and challenge questions will support the awarding of the A* grade at A Level, addressing the need for greater differentiation between the most able learners.

The use of scientific or graphical calculators are permitted in the written examinations. See Section 5e for further details.

Fundamentals of geology (Component 01)

This component is worth 110 marks and is split into two sections and assesses content from across all teaching modules 1 to 7. Learners answer all questions.

Section A contains multiple choice questions. This section of the paper is worth 25 marks.

Section B includes short answer and extended response questions covering structured questions, problem solving, calculations and practical skills. This section of the paper is worth 85 marks.

Scientific literacy in geology (Component 02)

This component assesses content from across all teaching modules 1 to 7 and places a particular emphasis on scientific literacy (see Section 2e). Learners answer all questions.

Question styles include short answer and extended response questions covering structured questions, problem solving, calculations and practical skills. This component is worth 100 marks.

Practical skills in geology (Component 03)

Module 1 of the specification content relates to the practical skills learners are expected to gain throughout the course, which are assessed throughout the written examinations and also through the Practical Endorsement (see Section 5g).

This component assesses content from across all teaching modules 1 to 7 and places a particular emphasis on practical skills. Learners answer all questions. This component includes an excerpt from a small-scale geological map.

Question styles include short answer and extended response questions covering structured questions, problem solving, calculations and practical skills. This component is worth 60 marks.

Practical Endorsement in geology (Component 04)

Practical activities are embedded within the learning outcomes of the course to encourage practical activities in the classroom which contribute to the achievement of the Practical Endorsement (Section 5g) as well as enhancing learners' understanding of geological theory and practical skills.

Opportunities for carrying out activities that could count towards the Practical Endorsement are indicated throughout the specification. These are shown in the Additional guidance column as **PAG1** to **PAG10** and **PAG12** (Practical Activity Group, see Section 5g). There are a wide variety of opportunities to assess **PAG11** throughout the qualification.

Performance in this component is reported separately to the performance in the A Level as measured through externally assessed components 01–03. This non-exam assessment component rewards the development of practical competency in geology and is teacher-assessed.

Learners demonstrate competence in the range of skills and techniques specified in Section 1.2 of the specification by carrying out a minimum of 12 assessed practical activities. The Practical Endorsement is teacher assessed against the Common Practical Assessment Criteria as specified in Section 5g.

Learners may work in groups but must demonstrate and record independent evidence of their competency. Teachers who award a pass to their learners must be confident that each learner consistently and routinely exhibits the competencies listed in Section 5g and has demonstrated competence in all the skills detailed in Section 1.2.1 and in all the apparatus and techniques detailed in Section 1.2.2 before completion of the A Level course. The practical activities provided by OCR are all mapped against the specification and assessment criteria.

3b. Assessment objectives (AO)

There are three Assessment Objectives in OCR A Level in Geology. These are detailed in the table below.

Learners are expected to demonstrate their ability to:

	Assessment Objective
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.

AO weightings in A Level in Geology

The relationship between the assessment objectives and the components are shown in the following table:

Component	% of overall A Level in Geology (H414)		
	AO1	AO2	AO3
Fundamentals of geology (H414/01)	17–19	16–17	6–7
Scientific literacy in geology (H414/02)	9–10	15–17	12–13
Practical skills in geology (H414/03)	4–6	9–10	8–9
Practical endorsement in geology (H414/04)*	N/A	N/A	N/A
Total	30–35	40–44	26–29

* The Practical Endorsement is assessed and reported separately from the overall A Level grade (see Section 5g).

3c. Assessment availability

There will be one examination series available each year in May/June to **all** learners.

All examined components must be taken in the same examination series at the end of the course.

This specification will be certificated from the June 2019 examination series onwards.

3d. Retaking the qualification

Learners can retake the qualification as many times as they wish. Learners must retake all examined components but they can chose to either retake the Practical Endorsement or carry forward (re-use) their most recent result (see Section 4a).

3e. Assessment of extended response

The assessment materials for this qualification provide learners with the opportunity to demonstrate their ability to construct and develop a sustained and coherent line of reasoning and marks for extended responses are integrated into the marking criteria.

Extended response questions which are marked using a level of response mark scheme are included in Components 01–03. These are indicated in papers and mark schemes by an asterisk (*).

3f. Synoptic assessment

Synoptic assessment tests the learners' understanding of the connections between different elements of the subject.

Synoptic assessment involves the explicit drawing together of knowledge, understanding and skills learned in different parts of the A Level course. The emphasis of synoptic assessment is to encourage the development of the understanding of the subject as a discipline. All components within OCR's A Level Geology qualification contain an element of synoptic assessment.

Synoptic assessment requires learners to make and use connections within and between different areas of geology, for example, by:

- applying knowledge and understanding of more than one area to a particular situation or context
- using knowledge and understanding of principles and concepts in planning experimental and investigative work and in the analysis and evaluation of data
- bringing together scientific knowledge and understanding from different areas of the subject and applying them.

3g. Calculating qualification results

A learner's overall qualification grade for A Level in Geology will be calculated by adding together their marks from the three examined components taken to give their total weighted mark.

This mark will then be compared to the qualification level grade boundaries for the relevant entry option to determine the learner's overall qualification grade.

A learner's result for their Practical Endorsement in geology component will not contribute to their overall qualification grade.

4 Admin: what you need to know

The information in this section is designed to give an overview of the processes involved in administering this qualification so that you can speak to your exams officer. All of the following processes require you to submit something to OCR by a specific deadline.

More information about the processes and deadlines involved at each stage of the assessment cycle can be found in the Administration area of the OCR website.

OCR's *Admin overview* is available on the OCR website at http://www.ocr.org.uk/administration.

4a. Pre-assessment

Estimated entries

Estimated entries are your best projection of the number of learners who will be entered for a qualification in a particular series. Estimated entries should be submitted to OCR by the specified deadline. They are free and do not commit your centre in any way.

Registration for the Practical Endorsement

The first cycle of monitoring the Practical Endorsement in geology, which requires all centres offering geology A level to be monitored within the first two years of teaching, will follow the same pattern as biology, chemistry and physics, with initial contact based on February 2017 entry data. The initial contact will be made with the exams officer who will pass information to the lead teacher for geology.

The monitoring of subsequent cycles of the Practical Endorsement will be based on prior entry data. OCR will identify centres that made entries with them, and plan to visit accordingly. Monitoring visits will be spread across the two years and will not follow any pattern whereby the second cycle is necessarily two years from the first visit.

Lead teachers are required to undertake the free online training provided (available at: https://practicalendorsement.ocr.org.uk) on the implementation of the Practical Endorsement and must then disseminate this information to all other teachers of that science within the centre so that each teacher can apply the standards appropriately.

Final entries

Final entries provide OCR with detailed data for each learner, showing each assessment to be taken. It is essential that you use the correct entry code, considering the relevant entry rules.

Final entries must be submitted to OCR by the published deadlines or late entry fees will apply.

All learners taking an A Level in Geology must be entered for one of the following entry options shown in the following table:

Entry option		Components		
Entry code	**Title**	**Code**	**Title**	**Assessment type**
H414	Geology	01	Fundamentals of geology	External assessment
		02	Scientific literacy in geology	External assessment
		03	Practical skills in geology	External assessment
		04	Practical endorsement in geology	Non-exam assessment (Visiting monitoring)
H414C*	Geology	01	Fundamentals of geology	External assessment
		02	Scientific literacy in geology	External assessment
		03	Practical skills in geology	External assessment
		80	Practical endorsement in geology – Carried forward*	Non-exam assessment (Carried forward)

*Entry option H414C should only be selected for learners who are retaking the qualification who want to carry forward their mark for the non-exam assessment. The carry forward option will be available for the first time from June 2020.

Private candidates

Private candidates may enter for OCR assessments.

A private candidate is someone who pursues a course of study independently but takes an examination or assessment at an approved examination centre. A private candidate may be a part-time student, someone taking a distance learning course, or someone being tutored privately. They must be based in the UK.

The A Level Geology qualification requires learners to complete a Practical Endorsement incorporating a minimum of 12 practical activities, allowing them to demonstrate a range of practical skills, use of apparatus and techniques to fulfil the Common Practical Assessment Criteria.

The Practical Endorsement is an essential part of the course and will allow learners to develop skills for further study or employment, as well as imparting important knowledge that is part of the specification.

Private candidates need to contact OCR approved centres to establish whether they are prepared to host them as a private candidate. The centre may charge for this facility and OCR recommends that the arrangement is made early in the course.

Further guidance for private candidates may be found on the OCR website: http://www.ocr.org.uk.

Head of Centre Annual Declaration

The Head of Centre is required to provide a declaration to the JCQ as part of the annual NCN update, conducted in the autumn term, to confirm that the centre is meeting all requirements detailed in the specification, including that they have provided all candidates with the opportunity to undertake the prescribed practical activities.

The Head of Centre is required to provide a declaration to the JCQ as part of the annual NCN update, conducted in the autumn term, to confirm that the centre is meeting all requirements detailed in the specification, including that they have provided all candidates with the opportunity to undertake the prescribed practical activities.

Any failure by a centre to provide the Head of Centre Annual Declaration will result in your centre status being suspended and could lead to the withdrawal of our approval for you to operate as a centre.

NEA Centre Declaration Form: Practical Skills Statement

The NEA Centre Declaration Form which can be found on the OCR website at www.ocr.org.uk/formsfinder contains a Practical Skills Statement for A Level Geology. Centres must provide this signed form to OCR confirming that they have provided at least **four** days of geological fieldwork for learners and that they have allowed learners to:

- undertake fieldwork in the contexts of virtual fieldwork, local fieldwork outside the classroom and unfamiliar outcrop geology
- undertake the practical techniques detailed in module 1.3 of this specification.

Please see the JCQ publication *Instructions for conducting non-examination assessments* for further information.

Any failure by a centre to provide a signed Practical Skills Statement to OCR in a timely manner (by means of the NEA Centre Declaration Form) will be treated as malpractice and/or maladministration.

4b. Special consideration

Special consideration is a post-assessment adjustment to marks or grades to reflect temporary injury, illness or other indisposition at the time the assessment was taken.

Detailed information about eligibility for special consideration can be found in the JCQ publication *A guide to the special consideration process.*

4c. External assessment arrangements

Regulations governing examination arrangements are contained in the JCQ *Instructions for conducting examinations*.

4d. Admin of non-exam assessment

Regulations governing arrangements for internal assessments are contained in the JCQ *Instructions for conducting non-examination assessments*. Appendix 1 of this document gives specific details for the Practical Skills Endorsement for A Level sciences designed for use in England.

OCR's Admin overview is available on the OCR website at http://www.ocr.org.uk/administration.

Carrying forward the Practical Endorsement in Geology

Learners who are retaking the qualification can choose to either retake the endorsement or carry forward their most recent result for that component (even if it was awarded by another awarding organisation).

To carry forward the result, you must use the carry forward entry option (see table in Section 4a).

Learners must decide at the point of entry whether they are going to carry forward the endorsement or not.

The result for the endorsement may be carried forward for the lifetime of the specification and there is no restriction on the number of times the result may be carried forward. However, only the most recent non-absent result may be carried forward.

4e. Results and certificates

Grade scale

A Level qualifications are graded on the scale: A*, A, B, C, D, E, where A* is the highest. Learners who fail to reach the minimum standard for E will be Unclassified (U). Only subjects in which grades A* to E are attained will be recorded on certificates.

Results for the A Level Geology Practical Endorsement will be shown independently of the qualification grade on the certificate. Learners who fulfil the requirements and reach the minimum standard will be awarded a Pass grade. Learners who fail to reach the minimum standard will be recorded as 'Not Classified' and this will also be reported on the certificate.

Results

Results are released to centres and learners for information and to allow any queries to be resolved before certificates are issued.

Centres will have access to the following results' information for each learner:

- the grade for the qualification
- the raw mark for each component
- the total weighted mark for the qualification.

The following supporting information will be available:

- raw mark grade boundaries for each component
- weighted mark grade boundaries for each entry option.

Until certificates are issued, results are deemed to be provisional and may be subject to amendment.

A learner's final results will be recorded on an OCR certificate. The qualification title will be shown on the certificate as 'OCR Level 3 Advanced GCE in Geology'.

4f. Post-results services

A number of post-results services are available:

- **Enquiries about results** – If you are not happy with the outcome of a learner's results, centres may submit an enquiry about results.
- **Missing and incomplete results** – This service should be used if an individual subject result for a learner is missing, or the learner has been omitted entirely from the results supplied.
- **Access to scripts** – Centres can request access to marked scripts.
- **Practical Endorsement** – Since monitoring and any potential request for further visits take place throughout the period of the qualification, there is no post-results service provided.

4g. Malpractice

Any breach of the regulations for the conduct of examinations and non-exam assessment work may constitute malpractice (which includes maladministration) and must be reported to OCR as soon as it is detected.

Detailed information on malpractice can be found in the JCQ publication *Suspected Malpractice in Examinations and Assessments: Policies and Procedures*.

5 Appendices

5a. Overlap with other qualifications

There is a small degree of overlap between the content of this specification and those for other AS levels and A Levels in Science and Geography.

Examples of overlap include:

Biology

- fossils as evidence for evolution
- fossils as evidence for classification.

Chemistry

- covalent network structures
- acid–carbonate reaction
- oxidation
- isotopes.

Physics

- wave theory
- energy transfers
- mechanical properties of matter
- density and pressure
- radioactive decay
- motion of and within fluids; viscosity.

Geography

- no overlap with DfE subject criteria (core content)
- tectonic hazards (where added by an individual awarding organisation as non-core content in their specification).

5

5b. Accessibility

Reasonable adjustments and access arrangements allow learners with special educational needs, disabilities or temporary injuries to access the assessment and show what they know and can do, without changing the demands of the assessment. Applications for these should be made before the examination series. Detailed information about eligibility for access arrangements can be found in the JCQ *Access Arrangements and Reasonable Adjustments.*

The A Level qualification and subject criteria have been reviewed in order to identify any feature which could disadvantage learners who share a protected Characteristic as defined by the Equality Act 2010. All reasonable steps have been taken to minimise any such disadvantage.

5c. 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 A Level Geology are listed below. Also listed are eight of the derived units (which have special names) selected from the SI list of derived units in the same source.

It is expected that learners will show understanding of the scientific quantities and corresponding units, SI base and derived units listed below.

They will be able to use them in qualitative work and calculations. These units and their associated quantities are dimensionally independent.

SI base units		
Physical quantity	**Unit**	**Unit**
Length	metre	m
Mass	kilogram	kg
Time	second	s
Current	ampere	A
Temperature	kelvin	K
Amount of a substance	mole	mol

SI derived units		
Physical quantity	**Unit**	**Unit**
Frequency	hertz	Hz
Force	newton	N
Energy	joule	J
Power	watt	W
Pressure	pascal	Pa
Electric charge	coulomb	C
Electric potential difference	volt	V
Electric resistance	ohm	Ω

Non-standard units		
Physical quantity	**Unit**	**Unit**
Time	day	d
Time	year – annum	a
Mass	tonne	t

5d. How Science Works (HSW)

The idea that science progresses through a cycle of hypothesis, experimentation, observation, development and review is encompassed in this section. It covers aspects of scientific thinking and aims to develop the scientific skills and conventions fundamental to the study of science. The section includes understanding of theories and applications of science, the practical aspects of scientific experimentation, and objective analysis and evaluation. This will enable learners to develop an understanding of the processes and methods of science and, through consideration of the different types of scientific enquiry, learners will become equipped to answer scientific questions about the world around them.

OCR's A Level in Geology encourages the development of skills, knowledge and understanding in science through opportunities for regular hands-on practical and fieldwork.

Learners will be required to have carried out practical activities, especially in field situations, which will contribute towards the direct assessment of practical skills. These skills, knowledge and understanding will also be assessed indirectly in written examinations in the context of these, and other, practical activities.

The practical activities highlighted as the minimum requirement within this specification must cover the use of apparatus and practical techniques identified for geology. The assessment of fieldwork apparatus and techniques must take place on unfamiliar outcrop geology.

How Science Works (HSW) was conceived as being a wider view of science in context, rather than just straightforward scientific enquiry. It was intended to develop learners as critical and creative thinkers, able to solve problems in a variety of contexts.

Developing ideas and theories to explain geological processes, is at the heart of geology. Learners should be aware of the importance that peer review and repeatability have in giving confidence to this evidence.

Learners are expected to understand the variety of sources of data available for critical analysis to provide evidence and the uncertainty involved in its measurement. They should also be able to link that evidence to contexts influenced by culture, politics and ethics.

Understanding *How Science Works* requires an understanding of how scientific evidence can influence ideas and decisions for individuals and society, which is linked to the necessary skills of communication for audience and for purpose with appropriate scientific terminology.

The examples and guidance within the specification are not exhaustive but give a flavour of opportunities for integrating HSW within the course.

HSW1	Use theories, models and ideas to develop geological explanations.
HSW2	Use knowledge and understanding to pose scientific questions, define geological problems, present scientific arguments and geological ideas.
HSW3	Use appropriate methodology, including information and communication technology (ICT), to answer geological questions and solve geological problems.
HSW4	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.
HSW5	Analyse and interpret data to provide evidence, recognising correlations and causal relationships, manipulate and extrapolate these sometimes incomplete data sets in both two and three-dimensions.
HSW6	Evaluate methodology, evidence and partial data sets, and resolve conflicting evidence.
HSW7	Know that scientific knowledge and understanding develops over time.
HSW8	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.
HSW9	Consider applications and implications of science in geology and evaluate their associated benefits and risks.
HSW10	Consider ethical issues in the treatment of humans, other organisms and the environment.
HSW11	Evaluate the role of geology within the scientific community in validating new knowledge and ensuring integrity.
HSW12	Evaluate the ways in which society uses science to inform decision making.

5e Mathematical skills requirements

It is a requirement within A Level Geology that at least 10% of the marks available assess the use of mathematical skills (in the context of geology) at a level of demand which is not lower than that expected at higher tier GCSE (9–1) Mathematics.

The table below provides some examples of the mathematical requirements which will be assessed in A Level Geology and how the application of skills may be assessed within a written exam.

All mathematical content will be assessed within the lifetime of the specification. Skills shown in bold type will only be tested in the full A Level course, not the standalone AS level course.

This list of examples is not exhaustive and is not limited to GCSE (9–1) examples. These skills could be developed in other areas of specification content from those indicated.

Learners are permitted to use a scientific or graphical calculator for all written examinations. Calculators are subject to the rules in the document Instructions for Conducting Examinations published annually by JCQ (www.jcq.org.uk).

Formulae used in A Level Geology

To address geology questions using mathematical skills, learners will need to be able to use and, in some cases, recall formulae and equations. Some of these will be mathematical equations applied in geological contexts, while others are formulae for geological concepts, which may need to be manipulated using standard mathematical algebraic techniques.

	Geological	Mathematical
Recall	• Magnification • Rates • Concentration factor • Return period • Lithostatic pressure • Phi (ϕ) scale • Surface Area to Volume ratio	All of GCSE (9–1) Maths recall including (but not limited to): • circumference and area of circle • surface area and volume of right prisms (including cylinders) • mean • percentage (to include %change, %yield and %error)
Provided	• Darcy's Law • Moment Magnitude scale • Radioactive decay • Stokes Law	• Surface area and volume of sphere • Chi squared • Mann-Whitney *U* • Spearman's rank • Standard deviation

GCSE (9–1) Mathematical formulae to recall

At AS and A Level Geology we assume knowledge of higher tier GCSE (9–1) Mathematics content. This includes (but is not limited to) the following list of formulae which learners will need to recall.

Note that learners should be familiar with the convention of using *r* for radius, *h* for height, *b* for base and *l* for length.

- Circumference of circle

  $circumference\ of\ circle = 2\pi r$

- Area of circle

  $area\ of\ circle = \pi r^2$

- Surface area of cuboid

  $Surface\ area\ of\ cuboid = 2(bh + bl + hl)$

- Surface area of right prism (including cylinder)

  $surface\ area\ of\ right\ prism = \Sigma(area\ of\ each\ face)$

- Volume of cuboid

  $volume\ of\ cuboid = hbl$

- Volume of right prism (including cylinder)

  $volume\ of\ right\ prism = area\ of\ cross\text{-}section \times height$

- Mean

  $\bar{x} = \frac{\Sigma x}{n}$

- Percentage (which can be used to calculate percentage change, percentage yield and percentage error)

  $$percentage\ change = \frac{new\ quantity - original\ quantity}{original\ quantity} \times 100$$

  $$\%\ yield = \frac{actual\ amount}{theoretical\ amount} \times 100$$

  $$\%\ error\ (uncertainty) = \frac{2 \times absolute\ uncertainty}{quantity\ measured} \times 100\%$$

Geological formulae to recall

The following are the geological formulae which learners will need to recall:

- Magnification

$$Magnification = \frac{size\ of\ image}{size\ of\ real\ object}$$

- Rates (e.g. geotherm, relative plate motion, radioactivity, sedimentation rate)

$$Rate = \frac{change\ in\ quantity}{time\ taken}$$

- Surface Area to Volume ratio

$$Ratio = \frac{Surface\ Area}{Volume}$$

- Concentration factor

$$concentration\ factor = \frac{grade\ of\ metal\ ore}{average\ crustal\ abundance}$$

- Return period

$$return\ period = \frac{number\ of\ years\ on\ record + 1}{number\ of\ events\ of\ that\ magnitude}$$

- Lithostatic pressure

$$p = pgh = density\ of\ rock \times g \times thickness\ of\ overburden$$

- Phi (ϕ) scale

$$\text{phi} = -log_2\left(\frac{diameter\ of\ grain\ in\ mm}{1}\right)$$

Mathematical formulae that will need to be used but not recalled

The following are the mathematical formulae which learners will be given in the exam, or in a list from which they select and apply as appropriate:

- Surface area of a sphere

  $$Surface\ area\ of\ sphere = 4\pi r^2$$

- Volume of a sphere

  $$Volume\ of\ sphere = \frac{4}{3}\pi r^3$$

- Chi squared

  $$\chi^2 = \Sigma \frac{(f_o - f_e)^2}{f_e}$$

- Mann–Whitney U

  U_1 is found by counting the number of values in sample 2 which exceed each of the values in sample 1.
  U_2 is found by counting the number of values in sample 1 which exceed each of the values in sample 2.

- Spearman's Rank Correlation Coefficient

  $$r_s = 1 - \frac{6\Sigma d^2}{n(n^2 - 1)}$$

- Standard Deviation

  $$s = \sqrt{\frac{\Sigma(x - \overline{x})^2}{n - 1}}$$

Note that critical values tables, or appropriate excerpts from these tables, will be provided in the assessment where needed.

Learners will need to be able to work out which 'degrees of freedom' or 'n' row, and which confidence column(s) is/are relevant to their analysis.

Geological formulae that will need to be used but not recalled

The following are the geological formulae which learners will be given in the exam, or in a list from which they select and apply as appropriate:

- Darcy's Law

  $$Q = -\kappa A\left(\frac{h_2 - h_1}{L}\right)$$

- Moment Magnitude scale e.g.

  $$M_w = \frac{2}{3} log E - 6.1$$

- Radioactive decay

  $$N = N_0 e^{-\lambda t}$$

- Stokes Law

  $$v = \frac{gd^2(\rho_p - \rho_w)}{18\eta t}$$

Mathematical skills for geology – M1 – M4 Coverage Table

Ref	Mathematical skills to be assessed	Exemplification of mathematical skill in the context of A Level Geology (assessment is not limited to the examples below)	Areas of the specification which exemplify the mathematical skill (assessment is not limited to the examples below)
M1 – Number			
M1.1	Recognise and make use of appropriate units in calculations	Candidates should demonstrate their ability to: • convert between units e.g. ppb to gram per tonne • use correct units as part of calculations for gold ore concentration factor • work out the unit for a rate e.g. sedimentation rate	1.1.2(b), 1.1.3(c), 2.1.1(c), 2.2.2(a), 3.1.2(e), 3.3.1(a), 5.2.1(b), 5.1.1(b), 5.5.1(a), 6.2.1(a)
M1.2	Recognise and use expressions in decimal and standard form	Candidates should demonstrate their ability to: • use an appropriate number of decimal places in calculations e.g. for a mean • carry out calculations using numbers in standard and ordinary form e.g. use of magnification • convert between numbers in standard and ordinary form • understand that significant figures need retaining when making conversions between standard and ordinary form e.g. 0.063 mm is equivalent to 6.3×10^{-2} mm	2.1.2(a), 2.1.3(b), 5.4.1(a)
M1.3	Use an appropriate number of significant figures	Candidates should demonstrate their ability to: • report calculations to an appropriate number of significant figures given raw data quoted to varying numbers of significant figures • understand that calculated results can only be reported to the limits of the least accurate measurement	1.1.3(c), 2.1.1(c), 3.2.1(f)
M1.4	Use ratios, fractions and percentages	Candidates should demonstrate their ability to: • calculate percentage yields • calculate surface area to volume ratio • use scales for measuring	2.1.1(c), 2.1.2(b), 3.1.2(e), 3.2.2(g), 5.3.2(a), 5.5.1(a)

Ref	Mathematical skills to be assessed	Exemplification of mathematical skill in the context of A Level Geology (assessment is not limited to the examples below)	Areas of the specification which exemplify the mathematical skill (assessment is not limited to the examples below)
M1.5	Make order of magnitude calculations	Candidates should demonstrate their ability to: • use and manipulate the magnification formula $\text{magnification} = \frac{\text{size of image}}{\text{size of real object}}$	2.1.1(a), 2.1.2(b), 2.1.3(c), 3.3.1(a)
M1.6	Estimate results	Candidates should demonstrate their ability to: • estimate results to sense check that the calculated values are appropriate	2.1.1(c), 3.1.2(e), 5.5.1(a)
M2 – Statistics and probability			
M2.1	Find arithmetic means	Candidates should demonstrate their ability to: • find the mean of a range of data e.g. the mean clast size	2.1.1(c), 2.1.3(b), 6.2.1(d)
M2.2	Construct and interpret frequency tables and diagrams, bar charts and histograms	Candidates should demonstrate their ability to: • 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 to 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	2.1.2(a), 2.1.3(c), 4.2.1(d)
M2.3	**Understand simple probability**	**Candidates should demonstrate their ability to:** • **use the terms probability and chance appropriately** • **understand the probability associated with return periods for geohazards**	**2.2.2(a), 6.1.2(a)**
M2.4	**Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are combined**	**Candidates should demonstrate their ability to:** • **calculate percentage error where there are uncertainties in measurement**	**1.1.4(d), 3.1.1(b)**

Ref	Mathematical skills to be assessed	Exemplification of mathematical skill in the context of A Level Geology (assessment is not limited to the examples below)	Areas of the specification which exemplify the mathematical skill (assessment is not limited to the examples below)
M2.5	Understand the principles of sampling as applied to scientific data	Candidates should demonstrate their ability to: • estimate optimum sample size from a plot of number of clasts sampled vs running mean of mean b-axis length	1.3.1(b), 1.3.1(c), 2.1.3(b), 2.2.1(b), 2.2.2(a), 7.2.3(c)
M2.6	Understand the terms mean, median and mode	Candidates should demonstrate their ability to: • 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**	2.1.3(b), 2.2.1(b), 4.1.2(a), 4.1.2(b), 4.1.2(d), 4.1.2(e), 7.2.3(c)
M2.7	**Know the characteristics of normal and skewed distributions**	**Candidates should demonstrate their ability to:** • **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**	**1.1.4(a)(b), 2.1.3(b), 2.1.3(c)**
M2.8	Understand measures of dispersion, including standard deviation and interquartile range	Candidates should demonstrate their ability to: • 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	2.1.3(b), 2.1.3(c), 4.1.2(c), 7.2.3(c)
M2.9	Plot two variables from experimental or other linear data	Candidates should demonstrate their ability to: • select an appropriate format for presenting data: bar charts, histograms, graphs, triangular diagrams and scattergrams	2.2.1(b), 2.2.2(a), 5.1.1(a), 6.2.1(a), 7.2.2(a)

Ref	Mathematical skills to be assessed	Exemplification of mathematical skill in the context of A Level Geology (assessment is not limited to the examples below)	Areas of the specification which exemplify the mathematical skill (assessment is not limited to the examples below)
M2.10	Use a scatter diagram to identify a correlation between two variables	Candidates should demonstrate their ability to: • interpret a scattergram e.g. rate of plate motion vs total length of subducting plate margin	2.2.1(b), 3.2.1(g), 5.3.2(a)
M2.11	**Plot variables from experimental or other circular data**	**Candidates should demonstrate their ability to:** • **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)**	**3.3.1(a), 4.1.2(a–e), 7.2.3(c)**
M2.12	**Select and use a statistical test**	**Candidates should demonstrate their ability to select and use:** • **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.** **Candidates will not be expected to recall the equations for the statistical tests.**	**2.1.3(b), 2.2.1(b), 4.1.2(a), 7.1.1(b)**
M3 – Algebra and graphs			
M3.1	Understand and use the symbols: =, <, <<, >>, >, $\propto$ and ~	No exemplification required	
M3.2	Change the subject of an equation	Candidates should demonstrate their ability to: • use and manipulate equations e.g. magnification	2.1.1(c), 3.1.2(e), 3.2.1(a), 5.1.1(a), 5.2.1(b), 6.2.1(a)
M3.3	**Substitute numerical values into algebraic equations using appropriate units for physical quantities**	**Candidates should demonstrate their ability to:** • **use a given equation e.g. Darcy's law** $Q = -KA\left(\frac{h_2 - h_1}{L}\right)$	**5.1.1(a), 5.2.1(b), 5.3.2(a), 6.1.1(a)**

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Ref	Mathematical skills to be assessed	Exemplification of mathematical skill in the context of A Level Geology (assessment is not limited to the examples below)	Areas of the specification which exemplify the mathematical skill (assessment is not limited to the examples below)
M3.4	**Solve algebraic equations**	**Candidates should demonstrate their ability to:** • **solve equations in a geological context e.g.** $\varphi = -\log_2\left(\frac{D}{D_0}\right)$	**2.1.3(c), 5.1.1(a), 5.2.1(b), 5.3.2(a), 6.1.1(a)**
M3.5	**Use calculators to find and use power, exponential and logarithmic functions**	**Candidates should demonstrate their ability to:** • **solve for unknowns in radionuclide decay problems e.g.** $N = N_0e^{-\lambda t}$	**5.3.2(a), 6.1.1(a)**
M3.6	**Use logarithms in relation to quantities that range over several orders of magnitude**	**Candidates should demonstrate their ability to:** • **use a logarithmic scale in the context of geology e.g. decay law of radioactivity, Udden–Wentworth grain size scale**	**2.1.3(c), 5.1.1(a), 5.3.2(a), 6.1.1(a)**
M3.7	Translate information between graphical, numerical and algebraic forms	Candidates should demonstrate their ability to: • 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	3.2.1(b), 3.2.2(d), 3.3.1(b), 5.3.2(c), 5.4.1(a), 6.2.1(c)
M3.8	Understand that $y = mx + c$ represents a linear relationship	Candidates should demonstrate their ability to: • 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	1.1.3(d), 3.2.2(d), 3.3.1(b)
M3.9	**Determine the slope and intercept of a linear graph**	**Candidates should demonstrate their ability to:** • **read off an intercept point from a graph e.g. the initial velocity of a velocity time graph for a density current**	1.1.3(d), 5.1.1(b)
M3.10	Calculate rate of change from a graph showing a linear relationship	Candidates should demonstrate their ability to: • calculate a rate from a graph e.g. geothermal gradient through the lithosphere	1.1.3(d), 3.2.1(a), 3.3.2(d), 7.2.2(a)

Ref	Mathematical skills to be assessed	Exemplification of mathematical skill in the context of A Level Geology (assessment is not limited to the examples below)	Areas of the specification which exemplify the mathematical skill (assessment is not limited to the examples below)
M3.11	**Interpret logarithmic plots**	**Candidates should demonstrate their ability to:** • **use logarithmic plots with decay law of radioactivity**	**2.1.3(b), 5.3.2(a)**
M4 – Geometry and measures			
M4.1	**Calculate the circumferences, surface areas and volumes of regular shapes**	**Candidates should demonstrate their ability to:** • **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**	**2.1.1(c), 3.1.1(g), 3.2.2(c), 5.3.1(b), 5.5.1(a), 5.5.1(f), 5.5.2(c), 6.2.1(a), 7.2.2(c)**
M4.2	Visualize and represent 2D and 3D forms, including 2D representations of 3D objects	Candidates should demonstrate their ability to: • 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 field sketches	2.1.2(b), 3.3.1(a), 4.1.2(a), 4.1.2(b), 4.2.1(a), 6.2.1(c)
M4.3	**Use sin, cos and tan in physical problems**	**Candidates should demonstrate their ability to:** • **determine true thickness of rock units** • **interpret block diagrams to show geological structures in 3D** • **crustal extension or shortening**	**3.3.1(a), 4.2.1(b)**

5f. Health and Safety

In UK law, health and safety is primarily the responsibility of the employer. In a school or college the employer could be a local education authority, the governing body or board of trustees. Employees (teachers/lecturers, technicians etc.), have a legal duty to cooperate with their employer on health and safety matters. Various regulations, but especially the COSHH Regulations 2002 (as amended) and the Management of Health and Safety at Work Regulations 1999, require that before any activity involving a hazardous procedure or harmful microorganisms is carried out, or hazardous chemicals are used or made, the employer must carry out a risk assessment. A useful summary of the requirements for risk assessment in school or college science can be found at: https://www.ase.org.uk

For members, the CLEAPSS® guide, *PS90*, *Making and recording risk assessments in school science*[1] offers appropriate advice.

Most education employers have adopted nationally available publications as the basis for their Model Risk Assessments.

Where an employer has adopted model risk assessments an individual school or college then has to review them, to see if there is a need to modify or adapt them in some way to suit the particular conditions of the establishment.

Such adaptations might include a reduced scale of working, deciding that the fume cupboard provision was inadequate or the skills of the learners were insufficient to attempt particular activities safely. The significant findings of such risk assessment should then be recorded in a '*point of use text*', for example on schemes of work, published teachers guides, work sheets, etc. There is no specific legal requirement that detailed risk assessment forms should be completed for each practical activity, although a minority of employers may require this.

Where project work or investigations, sometimes linked to work-related activities, are included in specifications this may well lead to the use of novel procedures, chemicals or microorganisms, which are not covered by the employer's model risk assessments. The employer should have given guidance on how to proceed in such cases. Often, for members, it will involve contacting CLEAPSS®.

[1] These, and other CLEAPSS® publications, are on the CLEAPSS® Science Publications website www.cleapss.org.uk. Note that CLEAPSS® publications are only available to members. For more information about CLEAPSS® go to www.cleapss.org.uk.

5g. Practical Endorsement

The Practical Endorsement for A Level Geology requires a minimum of 12 practical activities to be completed from the categories defined below (**Fig. 1**).

The practical activities can be completed at any point during the two-year A Level course at the discretion of the centre. Learners starting from a standalone AS level can count A Level practical activities carried out during the AS year towards the A Level Practical Endorsement provided that they are appropriately recorded. It is recommended therefore that learners starting AS maintain a record of practical activities carried out (e.g. this could be in the form of a 'log book' or 'practical portfolio') that could be counted towards the Practical Endorsement. For learners who then decide to follow a full A Level, having started from AS Level, they can carry this record with them into their A Level study.

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 are common to all awarding organisations. These arrangements include:

- A minimum of 12 practical activities to be carried out by each learner which, together, meet the requirements of Appendices 1b (*Practical skills identified for direct assessment and developed through teaching and learning*, covered in Section 1.2.1) and 1c (*Use of apparatus and techniques*, covered in Section 1.2.2) from the prescribed subject content, published by the Department for Education. The required practical activities are defined by each awarding organisation (see **Fig. 1** and **Table 1**)
- Teachers will assess learners against Common Practical Assessment Criteria (CPAC) issued by the awarding organisations. The CPAC (see **Table 2**) are based on the requirements of Appendices 5b and 5c of the subject content requirements published by the Department for Education, and define the minimum standard required for the achievement of a pass
- Each learner will keep an appropriate record of their practical work, including their assessed practical activities
- Learners who demonstrate the required standard across all the requirements of the CPAC, incorporating all the skills, apparatus and techniques (as defined in Sections 1.2.1 and 1.2.2), will receive a 'Pass' grade (note that the practical activity tracker available from OCR allows confirmation that the activities selected cover all the requirements)
- There will be no direct assessment of practical skills for AS qualifications
- Learners will answer questions in the AS and A Level examination papers that assess the requirements of Appendix 5a (*Practical skills identified for indirect assessment and developed through teaching and learning*, covered in Section 1.1) from the prescribed subject content, published by the Department for Education. These questions may draw on, or range beyond, the practical activities included in the specification.

In order to achieve a pass, learners will need to:

- develop these competencies by carrying out a minimum of 12 practical activities (**PAG1** to **PAG12**), which allow acquisition of all the skills, apparatus and techniques outlined in the requirements of the specification (Sections 1.2.1 and 1.2.2)
- consistently and routinely exhibit the competencies listed in the CPAC (**Table 2**) before the completion of the A Level course
- keep an appropriate record of their practical work, including their assessed practical activities
- be able to demonstrate and/or record independent evidence of their competency, including evidence of independent application of investigative approaches and methods to practical work.

The practical activities prescribed in the subject specification (**PAG1** to **PAG12**) will provide opportunities for demonstrating competence in all the skills identified, together with the use of apparatus and techniques for each subject. However, learners can also demonstrate these competencies in any additional practical activity undertaken throughout the course of study which covers the requirements of Appendices 1b and 1c (covered in Sections 1.2.1 and 1.2.2).

Learners may work in groups but teachers who award a pass to their learners need to be confident of individual learners' competence.

The Practical Activity Groups (PAGs)

OCR has split the requirements of Sections 1.2.1 and 1.2.2 and the Common Practical Assessment Criteria (**Table 2**) into 12 Practical Activity Groups (PAGs) as defined below (with further detail in **Table 1**). Opportunities for carrying out activities that could count towards the Practical Endorsement are indicated throughout the specification, in the guidance column, by using the labels **PAG1** to **PAG10** and **PAG12**. There are a wide variety of opportunities to assess **PAG11** throughout the specification.

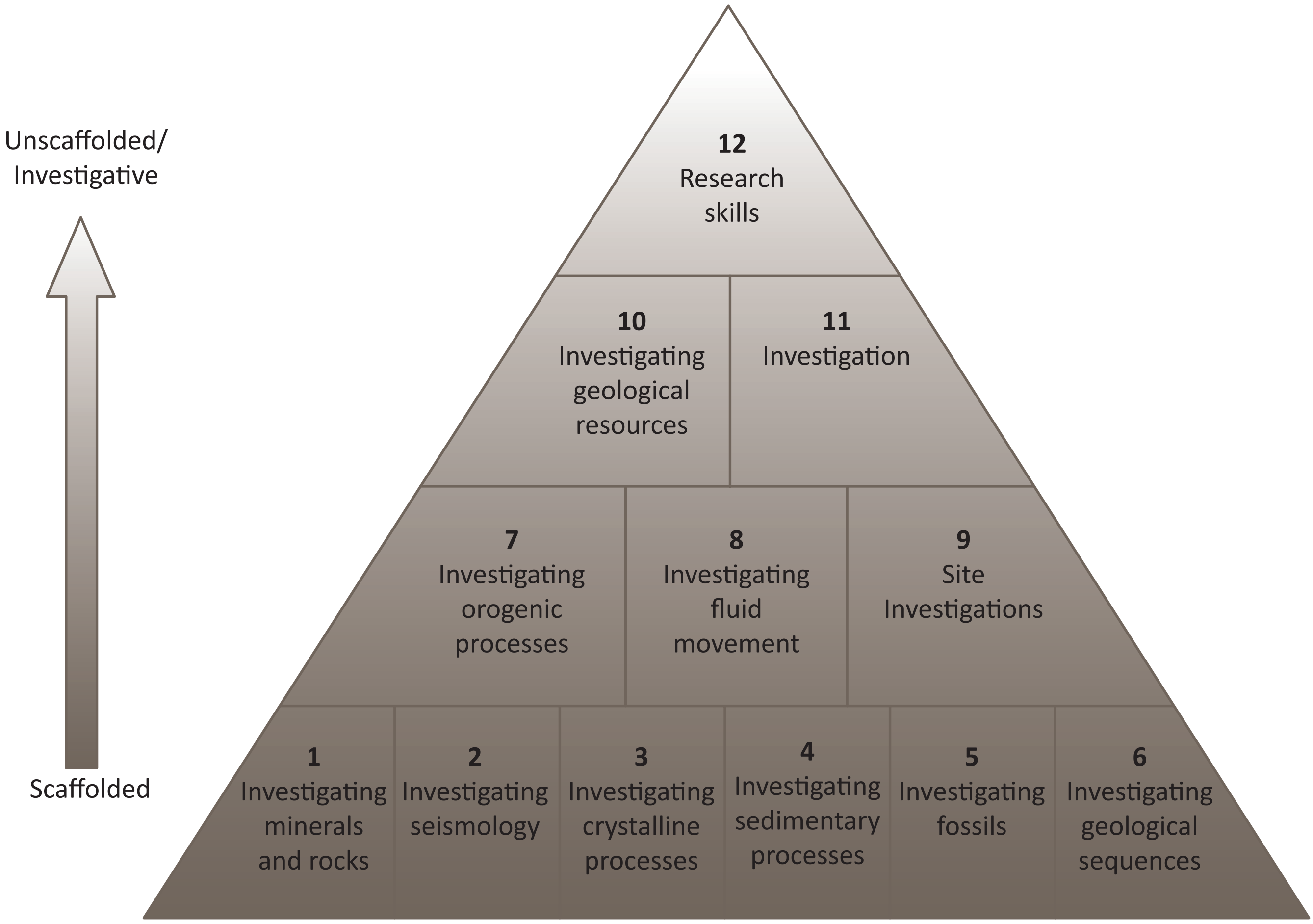

Fig. 1 OCR's Practical Activity Groups (PAGs), also see **Table 1**

Table 1: Practical activity requirements for the OCR Geology Practical Endorsement

Practical activity group (PAG)	Skills, apparatus and techniques covered *(where particular skills, apparatus and techniques are indicated in more than one group, they may be covered in any of the groups indicated)*	Example of suitable practical activity (a range of examples will be available from the OCR website or centres can devise their own activity)	Specification reference (examples)
1 Investigating minerals and rocks	• 1.2.2(g) produce annotated scientific drawings of fossils, or small scale features, from hand samples using a light microscope, or hand lens observation • 1.2.2(h) produce full rock descriptions of macro and micro features from conserved hand samples and unfamiliar field exposures • 1.2.2(i) use of photomicrographs to identify minerals and rock textures • 1.2.2(j) use appropriate apparatus to record a range of quantitative measurements (mass, time, volume, length) • 1.2.2(k) use of physical and chemical testing to identify minerals to include: (i) density test (ii) Mohs hardness test	Use keys, photomicrographs and investigation of hand specimens to identify rock types.	2.1.1(c), 2.1.2(a), 2.1.3(c) 2.1.3(d)iii, 2.1.4(b), 2.1.4(c)
2 Investigating seismology	• 1.2.1(g) use appropriate software and tools to process data, carry out research and report findings • 1.2.2(j) use appropriate apparatus to record a range of quantitative measurements (time) • 1.2.2(l) use methods to increase accuracy of measurements, such as timing over multiple observations • 1.2.2(m) use of ICT to: (i) compile and analyse geological data sets to enable visualisation using geographic information system (GIS) (ii) collect, process and model geological data	Investigation of seismic properties using a hammer source and geophone app on smartphones.	3.2.1(b), 3.2.2(d), 6.1.1(b)
3 Investigating crystalline processes	• 1.2.2(j) use appropriate apparatus to record a range of quantitative measurements (temperature and length) • 1.2.2(l) use methods to increase accuracy of measurements, such as use of a fiducial scale (in photograph/field sketch)	Investigate crystal size and rate of cooling using salol and microscope slides at different temperatures.	2.1.2(b), 3.2.2(e)ii, 5.3.1(a), 5.4.1(b)i

Practical activity group (PAG)	Skills, apparatus and techniques covered *(where particular skills, apparatus and techniques are indicated in more than one group, they may be covered in any of the groups indicated)*	Example of suitable practical activity (a range of examples will be available from the OCR website or centres can devise their own activity)	Specification reference (examples)
4 Investigating sedimentary processes	• 1.2.2(e) use sampling techniques in fieldwork • 1.2.2(g) produce annotated scientific drawings of fossils, or small scale features, from hand samples using a light microscope, or hand lens observation • 1.2.2(h) produce full rock descriptions of macro and micro features from conserved hand samples and unfamiliar field exposures • 1.2.2(j) use appropriate apparatus to record a range of quantitative measurements (length) • 1.2.2(l) use methods to increase accuracy of measurements, such as timing over multiple observations, or use of a fiducial scale (in photograph/field sketch)	Grain size analysis by sieving of sand samples from contrasting depositional environments.	2.1.3(b)ii, 4.1.2(a), 5.1.1(a), 7.2.3(a), 7.2.3(b)
5 Investigating fossils	• 1.2.2(f) apply classification systems using distinguishing characteristics to identify unknown minerals and fossils • 1.2.2(g) produce annotated scientific drawings of fossils, or small scale features, from hand samples using a light microscope, or hand lens observation • 1.2.2(l) use methods to increase accuracy of measurements, such as use of fiducial scale	Modelling taphonomic processes in the laboratory	2.2.1(a) 2.2.2(b), 7.1.2(a), 7.2.1(b)i, 7.2.2(e)iii
6 Investigating geological sequences	• 1.2.2(a) location of geological features in the field using traditional navigation and basic field survey skills without the use of GPS • 1.2.2(b) identification of geological structures in the field recording observations as field sketches • 1.2.2(c) 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 • 1.2.2(d) construct graphic logs using appropriate scale and symbol sets for unfamiliar geological sequences and exposures • 1.2.2(e) use sampling techniques in fieldwork • 1.2.2(h) produce full rock descriptions of macro and micro features from conserved hand samples and unfamiliar field exposures • 1.2.2(l) use methods to increase accuracy of measurements, such as use of a fiducial scale (in photograph/field sketch)	Field based investigation of an outcrop to determine geochronology and process of deposition and/or rock emplacement.	3.3.1(a), 4.1.2(a), 4.1.2(b), 4.2.1(a)

Practical activity group (PAG)	Skills, apparatus and techniques covered *(where particular skills, apparatus and techniques are indicated in more than one group, they may be covered in any of the groups indicated)*	Example of suitable practical activity (a range of examples will be available from the OCR website or centres can devise their own activity)	Specification reference (examples)
7 Investigating orogenic processes	• 1.2.2(f) apply classification systems using distinguishing characteristics to identify unknown minerals and fossils • 1.2.2(i) use of photomicrographs to identify minerals and rock textures • 1.2.2(j) use appropriate apparatus to record a range of quantitative measurements (to include mass, time, volume, temperature and length) • 1.2.2(l) use methods to increase accuracy of measurements, such as timing over multiple observations	Simulate fractional crystallisation as an ore producing process.	3.3.2(c), 5.3.1(c), 5.4.1(a), 5.4.1(b), 5.4.1(c)
8 Investigating fluid movement	• 1.2.1(g) use appropriate software and tools to process data, carry out research and report findings • 1.2.2(g) produce annotated scientific drawings of fossils, or small scale features, from hand samples using a light microscope, or hand lens observation • 1.2.2(i) use of photomicrographs to identify minerals and rock textures • 1.2.2(m) use of ICT to: (i) compile and analyse geological data sets to enable visualisation using geographic information system (GIS) (ii) collect, process and model geological data	Computer modelling of factors affecting flow in an aquifer using a spreadsheet	2.1.3(e)(iv), 5.2.1(a), 5.2.1(d), 6.2.1(c), 7.2.2(b)
9 Site investigations	• 1.2.2(a) location of geological features in the field using traditional navigation and basic field survey skills without the use of GPS • 1.2.2(c) 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 • 1.2.2(d) construct graphic logs using appropriate scale and symbol sets for unfamiliar geological sequences and exposures • 1.2.2(e) use sampling techniques in fieldwork • 1.2.2(h) produce full rock descriptions of macro and micro features from conserved hand samples and unfamiliar field exposures • 1.2.2(j) use appropriate apparatus to record a range of quantitative measurements (to include mass, time, volume, temperature and length) • 1.2.2(k) use of physical and chemical testing to identify minerals to include: (ii) Mohs hardness test • 1.2.2(l) use methods to increase accuracy of measurements, such as timing over multiple observations, or use of a fiducial scale (in photograph/field sketch)	Investigation of the factors controlling the strength of rocks and soil.	3.3.1(b), 6.1.2(c), 6.1.3(c), 6.2.1(a), 6.2.2(c)

Practical activity group (PAG)	Skills, apparatus and techniques covered *(where particular skills, apparatus and techniques are indicated in more than one group, they may be covered in any of the groups indicated)*	Example of suitable practical activity (a range of examples will be available from the OCR website or centres can devise their own activity)	Specification reference (examples)
10 Investigating geological resources	• 1.2.1(g) use appropriate software and tools to process data, carry out research and report findings • 1.2.2(a) location of geological features in the field using traditional navigation and basic field survey skills without the use of GPS • 1.2.2(b) identification of geological structures in the field recording observations as field sketches • 1.2.2(e) using sampling techniques in fieldwork • 1.2.2(f) apply classification systems using distinguishing characteristics to identify unknown minerals and fossils • 1.2.2(m) use of ICT to:(i) compile and analyse geological data sets to enable visualisation using geographic information system (GIS) (ii) collect, process and model geological data	Integrating fieldwork and secondary data sets with BGS GEOINDEX ONSHORE online GIS to model the exploration and development of a hydrocarbon play.	5.5.1(a), 5.5.1(c), 5.5.1(d), 5.5.1(e), 7.2.2(a) 7.2.2(d)
11 Investigation	• 1.2.1(a) apply investigative approaches and methods to practical work • 1.2.2(a) location of geological features in the field using traditional navigation and basic field survey skills without the use of GPS • 1.2.2(b) identification of geological structures in the field recording observations as field sketches • 1.2.2(c) 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 • 1.2.2(e) use sampling techniques in fieldwork • 1.2.2(f) apply classification systems using distinguishing characteristics to identify unknown minerals and fossils • 1.2.2(l) use methods to increase accuracy of measurements, such as timing over multiple observations, or use of a fiducial scale (in photograph/field sketch)	Investigate surface slopes during deposition using geopetal structures.	Opportunities throughout specification

Practical activity group (PAG)	Skills, apparatus and techniques covered *(where particular skills, apparatus and techniques are indicated in more than one group, they may be covered in any of the groups indicated)*	Example of suitable practical activity (a range of examples will be available from the OCR website or centres can devise their own activity)	Specification reference (examples)
12 Research skills	• 1.2.1(h) Use online and offline research skills • 1.2.1(i) Correctly cite sources of information • 1.2.2(a) location of geological features in the field using traditional navigation and basic field survey skills without the use of GPS • 1.2.2(b) identification of geological structures in the field recording observations as field sketches • 1.2.2(c) 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 • 1.2.2(d) construct graphic logs using appropriate scale and symbol sets for unfamiliar geological sequences and exposures • 1.2.2(e) use sampling techniques in fieldwork	Integrating learner's field geology study and secondary data (e.g. geological maps, seismic data, well logs, fossils) to understand the palaeoenvironments and geological history within the context of a basin wide study, as part of a practical investigation.	3.1.2(b), 5.3.2(b), 5.5.2(c), 5.5.2(d), 6.2.1(d), 7.1.1(a)iv, 7.1.2(b)iv, 7.2.2(d), 7.2.3(c)

It is expected that the following skills will be developed across all activities, regardless of the exact selection of activities. The ability to:

- 1.2.1(b) safely and correctly use a range of practical equipment and materials
- 1.2.1(c) follow written instructions
- 1.2.1(d) make and record observations/measurements
- 1.2.1(e) keep appropriate records of experimental activities
- 1.2.1(f) present information and data in a scientific way
- 1.2.1(j) use a wide range of experimental and practical instruments, equipment and techniques.

Table 2: Common Practical Assessment Criteria (CPAC)

Common Practical Assessment Criteria for the assessment of practical competency in A Level Geology.

Competency	*Practical Mastery*
	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.
(1) Follows written procedures	**a)** Correctly follows instructions to carry out the experimental techniques or procedures.
(2) Applies investigative approaches and methods when using instruments and equipment	**a)** Correctly uses appropriate instrumentation, apparatus and materials (including ICT) to carry out investigative activities, experimental techniques and procedures with minimal assistance or prompting. **b)** Carries out techniques or procedures methodically, in sequence and in combination, identifying practical issues and making adjustments when necessary. **c)** Identifies and controls significant quantitative variables where applicable, and plans approaches to take account of variables that cannot readily be controlled. **d)** Selects appropriate equipment and measurement strategies in order to ensure suitably accurate results.
(3) Safely uses a range of practical equipment and materials	**a)** Identifies hazards and assesses risks associated with these hazards when carrying out experimental techniques and procedures in the lab or field. **b)** Uses appropriate safety equipment and approaches to minimise risks with minimal prompting.
(4) Makes and records observations	**a)** Makes accurate observations relevant to the experimental or investigative procedure. **b)** 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	**a)** Uses appropriate software and/or tools to process data, carry out research and report findings. **b)** Cites sources of information, demonstrating that research has taken place, supporting planning and conclusions.

Choice of activity

Centres can include additional skills, apparatus and techniques within an activity beyond those listed as the minimum in **Table 1** or in the published practical activities. They may also carry out more than the minimum 12 practical activities required to meet the Practical Endorsement.

To achieve a Pass within the Practical Endorsement, candidates must have demonstrated competence in all the skills, apparatus and techniques detailed in Sections 1.2.1 and 1.2.2 of the specification by carrying out a minimum of 12 assessed practical activities (covering all of **PAG1** to **PAG12**) and achieved the level of competence defined within the Common Practical Assessment Criteria (**Table 2**).

The minimum of 12 activities can be met by:

- **(i)** using OCR suggested activities (provided as resources from Interchange, or by contacting pass@ocr.org.uk should you be unable to access Interchange)
- **(ii)** modifying OCR suggested activities to match available equipment whilst fulfilling the same skills, apparatus and techniques and CPAC
- **(iii)** using activities devised by the centre and mapped against Section 1.2 of the specification and the CPAC
- **(iv)** using activities from external sources such as the learned societies, mapped against Section 1.2 of the specification and the CPAC.

Centres can receive guidance on the suitability of their own practical activities or against any of the options within **(ii)** to **(iv)** above through our free practical assessment support service by emailing pass@ocr.org.uk.

Where centres devise their own practical activity or use an alternative activity, that practical activity must be of a level of demand appropriate for A Level.

Practical Activity Groups 1 to 12 can be achieved through more than one centre devised practical activity, and centres are not limited to 12 practical activities such that a centre could, for instance, split PAG1 into two activities of their own (rather than one), with the two activities fulfilling the requirements. Alternatively it could be possible that an extended activity may cover the requirements of more than one group, in which case the centre could then select an additional activity from another group to achieve the required minimum of 12 practical activities.

5h. Revision of the requirements for practical work

OCR will review the Practical Endorsement detailed in Section 5g of this specification following any revision by the Secretary of State of the skills, apparatus or techniques specified in respect of A Level Geology.

OCR will revise the Practical Endorsement if appropriate. If any revision to the Practical Endorsement is made, OCR will produce an amended specification which will be published on the OCR website.

OCR will then use the following methods to communicate the amendment to centres: subject information update emailed to all Examinations Officers, e-alerts to centres that have registered to teach the qualification and social media.

Summary of updates

Date	Version	Section	Title of Section	Change
December 2017	2	Multiple		Changes to generic wording and OCR website links throughout the specification. No changes have been made to any assessment requirements.
March 2018	3	5e	Mathematical skills requirements	Change to indicate mathematical formulae learners should be familiar with, those necessary to recall and those that will be presented in an assessment.
May 2018	3.1	4a	Pre-assessment	Update in line with new NEA Centre Declaration Form.
August 2018	3.2	3d 4d	Retaking the qualification Admin of non-exam assessment	Update to wording for carry forward rules.

YOUR CHECKLIST

Our aim is to provide you with all the information and support you need to deliver our specifications.

- Bookmark ocr.org.uk/alevelgeology for all the latest resources, information and news on A Level Geology
- Be among the first to hear about support materials and resources as they become available – register for Geology updates at ocr.org.uk/updates
- Find out about our professional development at cpdhub.ocr.org.uk
- View our range of skills guides for use across subjects and qualifications at ocr.org.uk/skillsguides
- Discover our new online past paper service at ocr.org.uk/exambuilder
- Learn more about Active Results at ocr.org.uk/activeresults
- Join our Geology social network community for teachers at social.ocr.org.uk

Download high-quality, exciting and innovative A Level Geology resources from ocr.org.uk/alevelgeology

Resources and support for our A Level Geology qualification, developed through collaboration between our Geology Subject Advisors, teachers and other subject experts, are available from our website. You can also contact our Geology Subject Advisors who can give you specialist advice, guidance and support.

Contact the team at:
01223 553998
science@ocr.org.uk
@OCR_Science

To stay up to date with all the relevant news about our qualifications, register for email updates at ocr.org.uk/updates

Geology Community

The social network is a free platform where teachers can engage with each other – and with us – to find and offer guidance, discover and share ideas, best practice and a range of Geology support materials.
To sign up, go to social.ocr.org.uk

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