GCE MARKING SCHEME

SUMMER 2016

GEOLOGY - GL5
1215/01-04

INTRODUCTION

This marking scheme was used by WJEC for the 2016 examination. It was finalised after detailed discussion at examiners' conferences by all the examiners involved in the assessment. The conference was held shortly after the paper was taken so that reference could be made to the full range of candidates' responses, with photocopied scripts forming the basis of discussion. The aim of the conference was to ensure that the marking scheme was interpreted and applied in the same way by all examiners.

It is hoped that this information will be of assistance to centres but it is recognised at the same time that, without the benefit of participation in the examiners' conference, teachers may have different views on certain matters of detail or interpretation.

WJEC regrets that it cannot enter into any discussion or correspondence about this marking scheme.

GCE GEOLOGY GL5

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Theme 1 – Quaternary Geology

Section A

1. *(a)* (i) **X** is gentle, **Y** is steep (1)

(ii) Gentle slope follows dip of beds (1) steep slope is scarp (1) cuesta (1)

(b) (i) Slopes mostly facing north east (1) fewer slopes to east (1) quantified (1)

(ii) North facing slopes sheltered from sun (1) less summer ablation/melting (1) prevailing wind blows snow to north and east (1) accumulated on sheltered NE facing slopes (1) Discussion of corrie formation processes (max 2)

(c) (i) As ice melts till is deposited (1) recessional moraine (1) ice snout static (1) + (1) for development ice bulldozes sediment (1) as it advances (1)

(ii) Interglacial deposit (1) water in hollow (1) trapped behind ridge (1) moss/plants grow (1) accumulate in waterlogged conditions (1) lake deposit (1) other reasonable explanation (1)

(iii) Active layer in permafrost caused by melting near surface - sediment loses cohesion and moves downhill, large solifluction lobe

Could be unrelated to periglacial conditions tension cracks show unstable ground, backward tilting blocks show movement on steep slope. Could be related to deglaciation – lack of support for valley side or it happened before most recent glaciation

Holistic mark

Section B

2. *"The geological structure and lithology of an area controls the drainage patterns of water both above and below the surface." Evaluate this statement.*

Effects of structure and / or lithology in production of:
Radial drainage (domes, volcanoes etc)
Trellised drainage (dipping rocks, basin & range etc)
Dendritic drainage (homogenous geology)
Superimposed drainage
Dry valleys Groundwater flow (aquifers, aquicludes etc)
Subterranean river courses
Springs

Breadth versus depth but must cover surface and groundwater
Credit use of examples

3. (a) *Explain the changes that occur in sea level in response to changes in the amount of continental ice.*

Isostatic changes in response to mass of ice locally on the continents, displacing the mantle
Eustatic changes in response to changing volumes of continental ice and seawater during glacial/interglacial cycles
Superimposition of the two cycles of sea level change (and their differing rates) which create the landforms and evidence seen today (rias, fjords, raised beaches, submerged forests etc)

(b) *Evaluate the use of radiocarbon (^{14}C) dating in establishing a timescale for sea level changes.*

Timescale provided by dating ONLY organic material by ^{14}C dating
Small quantities of radioactive 14C incorporated into living organisms from atmosphere
Dates wood in submerged forests or carbonate in shells from raised beaches
Accurate dates
Decays over time / short half-life of 5730 years
Problems of short period of time that can be accurately dated (40-60,000 years BP)
Problems of contamination & variation in production rates of ^{14}C
Could use other techniques such as Zone fossils within Quaternary for relative dating and correlation

Must evaluate for access to full marks

4. (a) *Explain how the link between process and product in one named modern sedimentary environment can enable the reconstruction of earlier environments.*

Concept of Uniformitarianism
May choose examples of modern carbonates, turbidite environments, or other modern sedimentary environment (e.g. coast)

Carbonates
Biological processes
Reef building, reef deposits containing corals and other fauna
Conditions for coral growth (temperature, depth, light)
Symbiotic relationship with algae
Remains of marine algae – Coccoliths
Frequently bioturbated. Burrows preserved with other fossils

Physical Processes
Energy of environments, wave action of sea in warm shallow lagoon transporting ooids/pisoliths, high energy environment, relationship of ooid size and energy levels
Eroded clasts of limestone, fossil fragments – shell lags
Low energy back-reef lagoons

Chemical processes
Calcareous precipitate from evaporation of seawater
Formation of ooids, precipitation of micrite in back-reef basin/lagoon with shallow marine fossils, deposition as deep water muds with plankontic fossils

Turbidites
Changing Energy
Graded bedding, repeated cycles of sedimentation, Bouma sequences, flat laminations and cross bedding all give good data on the cyclic changes of energy in a turbidite environment.

Erosive processes
Sole structures (prod/bounce/groove marks and flute casts) can give good data on the orientation of the flow. Flute casts and Cross bedding can give accurate data on palaeocurrent direction.

Post depositional processes
Convolute bedding and load casts only give an indication of the post-depositional processes as the sediments de-water.

Other modern sedimentary environments are acceptable
Must be related to processes for access to full marks
Must name and discuss one environment for access to full marks

(b) *Evaluate the use of the Hjulström graph in interpreting lithologies in modern and ancient sedimentary environments.*

Hjuslstrom curve derived experimentally
Logarithmic scale to accommodate wide range of grain sizes and velocities
Relationship between flow velocity in a river and grain size
Shows range of velocity that will erode, transport and deposit grains
Allows geologists to apply uniformitarianism to reconstruct ancient river speeds from grain size of sediments
Only applies in water and to disaggregated sediment

Must evaluate for access to full marks.

Theme 2 – Geology of Natural Resources

Section A

1. *(a)* 3 300 m (accept 3 200-3 400 m)

(b) (i) Unconformity/stratigraphic trap (1) & fault trap (1)

(ii) micro plankton accumulate as source rock deposits (1) hydrocarbons migrate from source rock (1) moves through permeable reservoir rock (1) buoyant in water (1) stopped by impermeable cap rock (1) stratified by density (1)
max (2) if no reference to stratigraphy of Brent field

(iii) Variations in permeability (1) different size of pores (1) variations in viscosity of crude oil (1) fluid pressure in the reservoir (1) development of secondary permeability (1)

(c) (i) Oil & gas can be formed from marine kerogen (1) oil and gas can form at the same temperatures (1) the source rocks were heated to between 10 and 140°C (1)

(ii) coal as source rock (1) produces methane as part of maturation (1) terrestrial type of kerogen (1)

(d) Large volume pore space in Permian sandstones/permeable Permian sandstone (1) faults permeable (1) natural trap already stored gas (1) deep enough to maintain pressure on CO2 (1) evaporites would be poor – impermeable (1)
However: offshore location increases engineering problems (1) and expense (1)
Holistic answer

Section B

2. (a) *Evaluate the use of geophysical surveying in prospecting for metalliferous mineral resources.*

Seismic surveying
seismic /explosions / land / ship / reflection / record of 2-way time / graphical representation to identify structures

Magnetic Surveying
magnetometer / land / plane / ship / graphical representation of magnetic readings / depends on changes in magnetic properties or distribution of rocks i.e. structures / anomalies, iron deposits

Gravity Surveying
gravimeter / changes in gravity / changes in density of the underlying rocks / reflects the rocks / minerals / structure(s) / graphical representation / anomalies. High density metal minerals

Electrical surveying
Resistivity & conductivity of metalliferous deposits

Evaluation

Advantages:	speed / accuracy / cheap? Can locate hidden resources at depth
Disadvantages:	depends on target / cost? Cannot prove existence of deposit Only one stage in the exploration process

(b) *Evaluate the use of geochemical prospecting techniques in prospecting for metalliferous mineral resources.*

Sampling stream, soil or vegetation to find particular trace element concentrations which might indicate the presence of an economic resource
Heavy mineral sampling from sediment
Concentrations vary with distance from the ore body
Copper and lead

Evaluation
Advantages: sampling allows large catchment area to be investigated quickly all elements have a characteristic signatures which may show up in vegetation response and are easily recognised in soil and water samples very dependable and cost effective
Can use elements that occur in association with metals (eg Arsenic with gold deposits)
Can narrow down area to be investigated

Disadvantages: Contamination can be a problem (earlier mining, processing, wind-blown, flooding)
Background rocks, variations in water pH, and ore concentrations can give misleading results.
Insoluble metal deposits may not register.
Access may be difficult over wider areas.

3. (a) *Evaluate the importance of igneous processes in the formation of **metalliferous** ores.*

Igneous processes
cumulates
magmatic segregation
pegmatites
hydrothermal

Credit relevant examples: cassiterite, chalcopyrite, galena, sphalerite, haematite, wolframite etc.
Credit links to tectonic settings / rock cycle.

(b) *Evaluate the importance of sedimentary processes in the formation of **metalliferous** ores.*

Sedimentary processes
Metalliferous ores:
placer deposits (e.g. gold)
residual deposits (e.g. bauxite)
precipitated (e.g lithium deposits)
weathering (e.g. Malachite & Azurite)

Credit other examples: BIFs, manganese nodules etc
Credit links to rock cycle processes

Processes concentrating metals into economically viable deposits.

4. *"Interference with the surface and/or subsurface environment from the extraction of geological raw materials can be minimised by planning"*

Evaluate this statement with reference to the ways in which any adverse effects can be limited.

Answer depends upon hosen examples of raw materials.
Suggestions - coal extraction by deep mining/open cast
salt extraction by brine pumping/underground mining
onshore oilfield development
quarrying for roadstone / aggregate
sand and gravel extraction
Metal mining
China Clay extraction
Other examples are acceptable

Evaluation:
N.B. For access to full marks must evaluate the problems.

Potential environmental problems e.g. Noise, dust, pollution of water courses by chemical/waste, waste disposal etc
And the ways by which these may be minimised e.g. restricted blasting, baffle banks, settling tanks, backfill etc.
How significant are the problems and the way(s) that they are minimised?
Case studies to show planning to satisfy local or national legislation for max levels of pollution.

Theme 3 – Geological Evolution of Britain

Section A

1. *(a)* Antiform/anticline (1), vertical/very steep northern limb (1), gentle/low dip southern limb (1), rounded hinge (1), interlimb angle approx. 80° (1), open fold (1), inclined fold (1), asymmetric (1), overturned (northern) limb (1), E-W trending (1)
Any four (4)

(b) Alpine (1**R**)

E-W trending fold (1), mean strike 102-282, N-S compression (1), located in southern England (1), folding affects late Jurassic and early Cretaceous strata (1)

(c) Ammonite/ammonoid/cephalopod (1), trace fossil/track/footprint (1)

(d) Non-marine/sabkha/playa lake/swamp/lagoon/hypersaline sea/desert (1**R**)
Evaporites (halite, gypsum, limestone) = arid (1), mudcracks = arid (1), marl = low energy (1), carbon-rich layer (fossil soil) = swamp (1), trees = non-marine (1), trackway = land (1), limestone = tropics/warm (1)

(e) Non-marine sequence/ fossils (1), lack of (zone) fossils (1), lack of ammonites/ammonoids (1) possible periods of non-deposition/ erosion (1)
Credit any discussion of microfossils (1)

Section B

2. *(a)* *Describe the large scale structures and rock types (igneous and metamorphic) of the Variscan orogenic belt in Britain.*

Description: Main Variscan effects in SW Britain affecting Devonian-Carboniferous rocks.
Structures: Trend of structures mainly E-W but variable further north e.g. N-S Pennine anticline. Tight vertical, recumbent and overturned folding in SW Britain. Various thrust faults e.g. Lizard thrust. Deformation less intense further north from Variscan front to include open folds e.g. Pennine anticline and even extensional faults e.g. Midland Valley.
Igneous: Lizard ophiolite. Granitic Cornubian batholiths & mineralisation in Cornwall. More mafic activity elsewhere in Britain –Midland-Valley & Whin sills.
Metamorphism: Contact met surrounding Cornubian batholith. Low (slate) - medium (schist) grade regional met e.g. Start Bay. However minimal.

(b) *Evaluate the use of these large scale structures and rock types in the reconstruction of the plate tectonic setting of Britain during the Carboniferous and Permian.*

Evaluation: Thrusting / folding consistent with destructive plate margin with N-S compression producing E-W trending structures. Regional metamorphism in SW Britain nearer centre of collision zone with most intense deformation/ metamorphism. Partial melting of base of Variscan continental crust followed by crystal fractionation and crustal assimilation to explain the Cornubian batholith and associated igneous activity. Obduction of Lizard ophiolite consistent with accretion at destructive plate margin. South Wales foreland basin. Lack of andesitic volcanics problematic. Normal faulting and mafic volcanism/plutonism suggesting tension behind Variscan front- back arc basin? N-S orientation of structures in northern England records role of basement structures and localised extension.

3. *(a)* *Describe the rocks and fossils of the late Palaeozoic and/or early Mesozoic 'red beds' which suggest that they were formed in a variety of terrestrial environments.*

Description: Devonian and Permian-Triassic desert sub-environments:
Desert dunes: Red sandstones / haematite-iron oxide staining / well sorted, rounded / orthoquartzites/ aeolian dune bedding/ current ripples. Paucity of fossils- reasons.
Desert salt (playa) lakes: evaporates / halite/ gypsum/ limestone/ accept discussion of Zechstein sea/ desiccation cracks. Rare fossils / tracks / trails / footprints.
Desert wadi: breccias and alluvial fans/ angular/ poor-sorting/ immaturity/ calcretes etc./ graded bedding/ cross bedding. Paucity of fossils- reasons.

(b) *Evaluate the reliability of the palaeomagnetic evidence which indicates that Britain drifted north across the Equator during the late Palaeozoic and into the Mesozoic.*

Evaluation: Reliable data will give low angle magnetic inclination, decreasing to zero and then to a low angle again
Assumes dipolar field
Assumes rocks undisturbed i.e. no corruption of data e.g. tectonic/ metamorphism/ Curie temps.
Assumes geographic and magnetic poles close together.
Inaccuracies in radiometric dating methods.

4. *'Our confidence in interpreting sedimentary environments of deposition decreases with geological time.' Evaluate this statement.*

Reliance on Principal of Uniformitarianism which may in many cases be less reliable with time.
Physical processes constant through time e.g. value of g and viscosity of air/water. Consequently sedimentary structures e.g. graded bedding formed in identical way in past to present/ Hjustrom curve always applicable.
Chemical processes also reliable with time e.g. solubility of various ions in oceans and activation energies for various chemical weathering reactions. However, variable atmospheric conditions in past e.g. higher CO_2 through most of geological time and higher O_2 in Carboniferous may well have influenced rates of chemical weathering and mineral precipitation etc.
Biological factors more variable because of evolution and extinction. Several groups of organisms extinct (graptolites) closest modern day relative's different (trilobites-horseshoe crabs) environmental niches change e.g. brachiopods/ coral groups/ crinoids. Modern sediments better fossil preservation potential.
Older sediments also more likely to have been structurally deformed/ metamorphism/ diagenesis.
Other approaches to this question are more than acceptable.

Theme 4 – Geology of the Lithosphere

Section A

1. *(a)* Six areas of Archean crust (1)
Three areas of Archean crust north of Phanerozoic crust/ three areas of Archean crust south of Phanerozoic crust (1)
Archean surrounded/ enclosed /separated by Proterozoic crust (1)
Phanerozoic surrounded /enclosed /separated by Proterozoic crust (1)
Two belts of Phanerozoic crust (1) belts of Phanerozoic crust trend E-W (1)
Proterozoic on coastline (1) Any quantification of size of specific rock area (1)
Any three (3)

(b) (i)

The present day volume of the continental crust	7.7 - 7.9 × 10^9 km^3
The age of the oldest continental crust according to model **B**	4.4 - 4.5 × 10^9 years
The eon where the maximum rate of continental growth took place according to model **C**	Archean

(ii) (7.7 - 7.9 × 10^9)/ (4.4 - 4.5 × 10^9) (1)
expect answer in range 1.6 – 1.8 km^3/yr (1) ecf (i)

(iii) model A first continental crust in the Hadean yet model D first continental crust in the Archean (1) model A greatest rate of growth of continental crust in the Hadean yet model D greatest rate of growth of continental crust in the Proterozoic (1)
Model A shows a marked non-linear growth of continental crust yet model D shows a general steady growth of continental crust (1)
Model A indicates 'loss' of continental crust (since late Proterozoic) (1)
Any three (3)

(c) No mark for agree or disagree

Supports model C	Undermines model C
no Hadean rocks in Africa (1)	Africa has less Archean crust (~50%) than Model C suggests (~80%) (1)
very small (<5%) of Phanerozoic rocks in Africa (1)	Africa has more Proterozoic crust (~45%) than Model C suggests (~15%) (1)

Any statement questioning comparison of outcrop areas to volume values/ Africa to global data (1)
Model B better represents African age distribution data/ Combination of models B and C best represents African age distribution data (1)

Section B

2. *(a)* *Describe the layered structure and composition of an ophiolite sequence.*

Description

Layer	Composition
Deep sea sediments- several hundred metres thick	Pelagic sediments, red clays, cherts, chalks, turbidites (greywackes)
Pillow lavas and hylaclastites- submarine extrusives several hundred metres thick	Mafic, basalts, plagioclase and augite (olivine)
Dykes (often sheeted)- tabular intrusives- km or more thick	Mafic, dolerites, plagioclase and augite (olivine)
Plutonic intrusives- may be layered with cumulate structure- few km thick	Mafic, gabbros, plagioclase and augite (olivine). Fractionated plagiogranites possible.
Seismic Moho	
Mantle Cumulates- several tens or hundreds metres thick	Ultramafic, peridotites/dunites, olivine and augite
Petrological Moho	
Residual mantle- up to ten km thick	Ultramafic, peridotites/serpentenites, olivine and augite
Metamorphic sole- several tens or hundreds metres thick	Highly deformed (foliated) upper layers

Credit diagrams.
Definition and origin: pieces of oceanic plate that have been thrusted (obducted) onto the edge of continental plates.
Examples e.g. Oman, Cyprus, Lizard.

(b) *Evaluate the use of ophiolites in understanding the layered structure and composition of oceanic lithosphere.*

Evaluation

Huge advantage as samples and structure can be readily examined without recourse to drilling or geophysical techniques.
Structure- Layered structure usually very evident on large scale and can be easily matched to seismic layers 1, 2 and 3 of oceanic lithosphere or to ODP/DSDP boreholes. May however be confused by faulting (thrusting) and folding.
Composition- Similarity of ophiolite mineral assemblages to oceanic lithosphere confirmed by dredging and drilling. However, subtle differences may be due to different origins (back-arc basins hence more intermediate) and weathering. Major differences may result from regional metamorphism producing amphibolite and greenschist facies.

3. (a) *Describe the main processes responsible for lithospheric thickening in orogenic belts.*

Description

Definition of orogenic belt: arcuate range of mountains formed by ocean-continent/ continent-continent collision.
Examples e.g. Himalayas/Alps/Andes.
Main processes of crustal thickening- plate convergence/ compressive stress (principal stress directions)/ brittle thrusting/ ductile folding/ crustal shortening/ fold and thrust belts/ nappes/ overfolds/ island arc accretion/ accretionary wedge/ granite magmatism/ ophiolites.
Credit diagram

(b) *'Erosion is the main factor influencing the height of mountain ranges in orogenic belts.' Evaluate this statement.*

Evaluation

Erosion is an important factor in reducing the thickness of the lithosphere and hence also the height of mountain ranges. Gravitational collapse may also lead to a similar scenario. Conversely, material added to continent during collision thickens the lithosphere mainly 'downwards' and slightly 'upwards' leading to an increase in the height of mountain ranges. Delamination may also lead to a rapid increase in the height of mountain ranges. It is therefore the balance between erosion and this addition of new material i.e. isostasy which determines the height of mountain ranges. As many orogenic belts are not in isostatic equilibrium such generalisations are therefore too simplistic.

4. *Evaluate the use of seismic techniques in investigating the structure of the lithosphere.*

Description

Introduction to seismic surveying techniques - refraction and reflection. Discussion of seismic body (P and S) waves. Use of deep seismic reflection surveys e.g. BIRPS and COCORP to investigate crustal structure. Recognition of seismic discontinuities e.g. Mohorovicic using refraction techniques. Seismic layers 1, 2 and 3 in the oceanic crust. Conrad discontinuity? In the continental crust. Ray path models through crust and upper mantle. P and S wave velocity-depth curves. Identification of seismic low velocity zone.

Evaluation

Seismic methods provide best way of deducing structure of wide areas in relatively quick time. Seismic resolution very good for shallow depths but resolution decreases for greater depths.
Need to rely on few deep boreholes (e.g. Kola super-deep borehole), geochemical experiments, geophysics e.g. gravity surveys.

MARK BAND CRITERIA FOR A2 ESSAYS

Summary Description	Marks out of 25	Criteria
Outstanding	25-23	Not the perfect answer, but a candidate could not be expected to produce better work at this level in the time allowed.
Very good	22-20	Arguments are purposeful, well supported & show both balance and style. Irrefutable evidence of a thorough grasp of concepts & principles. A hint of flair apparent in work.
Good	19-17	The answer is direct & explicit; shows the ability to use knowledge & understanding & to discuss. May be limited in terms of supporting material & breadth of coverage.
Quite good	16-14	Shows a reasonably secure grasp of the basics, but answer may show some slight deficiencies in terms of either knowledge & understanding or directness & organisation.
Modest	13-11	Material is mainly relevant & sound, but points need more development (& support). Could be much more direct & explicit in approach.
Minimal	10-8	Work impoverished by limited knowledge & understanding; tendency to rehash prepared material & to answer by inference. Answer rather hit & miss.
Weak	7-5	Little evidence of knowledge or understanding; unable or unwilling to address the question; essentially random in approach.
Very weak	4-1	Largely irrelevant; too brief; abundant erroneous material.
Unacceptable	0	Wholly irrelevant or nothing written.

Incorporated into this mark scheme is the assessment of candidates on their ability to organise & present information, ideas, descriptions & argument clearly & logically, taking into account their use of spelling, punctuation & grammar.

QUICK GUIDE

Description		K / U	Discussion	Terminology
Outstanding	23-25	Not perfect BUT		Thorough
Very good	20-22	Thorough grasp	Well supported Hint of flair + EVALUATION	Sound
Good	17-19	Direct/explicit	Limited support - breadth Lacks detail - depth	Significant
Quite good	14-16	Basics	Slight deficiencies. Limited scope relevance	Basic
Modest	11-13	Mainly relevant	Needs much more development	
Minimal	8-10	Limited/rehash	Hit and miss	Little
Weak	5-7	Little evidence	Question not addressed	
Very weak	1-4	Irrelevant/erroneous	Too brief	
Unacceptable	0			

Thus key dividing lines are:

Outstanding - Across the board – no significant weaknesses

Very good - EVALUATION

Good - Good read - some omissions in content/detail/discussion

Quite good - Essay title has been addressed but not a convincing argument

Modest - Bit difficult to follow. Do they really know?
Addressed the question but need much more discussion = mark scheme

Minimal/Weak/Very weak - Rehash at best - irrelevant material/no essay to mark/mark per point?