2025/4477
Web version of 2024/81657

Government of **Western Australia**
School Curriculum and Standards Authority

EARTH AND ENVIRONMENTAL SCIENCE

ATAR course examination 2024

Marking key

Marking keys are an explicit statement about what the examining panel expect of candidates when they respond to particular examination items. They help ensure a consistent interpretation of the criteria that guide the awarding of marks.

Section One: Multiple-choice **15% (15 Marks)**

Question	Answer
1	a and d
2	a
3	b
4	c
5	b
6	c
7	d
8	a
9	b
10	b
11	c
12	a
13	d
14	d
15	b

Section Two: Short answer **55% (110 Marks)**

Question 16 **(11 marks)**

(a) Using the information in the diagram above, describe how tectonic processes restrict the areas where geothermal energy can be economically harnessed. (3 marks)

Description	Marks
States that geothermal energy locations are generally close to tectonic plate boundaries	1
States that active plate boundaries are areas of increased geothermal gradient	1
States that standard geothermal gradient in continental interiors is insufficient for economic geothermal power production	1
Total	**3**

Sample answer:

Tectonic setting is critical to the viability of geothermal energy fields. All high-temperature geothermal resources suitable for energy production are associated with active tectonic areas. Countries on tectonic plate boundaries, such as New Zealand or Iceland, utilise geothermal heat produced through volcanism located at shallow depths to generate energy. Where high-temperature gradients are absent, such as in typical continental interiors, accessing rocks hot enough for their heat to power electricity production costs too much to make geothermal electricity economic.

Accept other relevant answers.

(b) Outline **one** tectonic hazard associated with areas where geothermal energy can be produced on a large scale. (2 marks)

Description	Marks
Identifies tectonic hazard	1
States how the tectonic hazard is associated with geothermal energy locations	1
Total	**2**

Answers could include:

- volcanism – areas suitable for geothermal energy production on a large scale are mostly located at plate boundaries or areas of high volcanism. The volcanism is required to produce the high geothermal gradients in the zone; however, volcanic eruptions could destroy infrastructure
- earthquakes – are a hazard at most geothermal energy locations due to the constant movement of the tectonic plates. Earthquakes can compromise the stability of infrastructure.

Accept other relevant answers.

Question 16 (continued)

(c) Outline **two** environmental factors that should be considered before an investment in geothermal energy production is made. (4 marks)

Description	Marks
For each environmental factor (2 x 2 marks)	
Identifies an environmental factor	1
States how the chosen factor would influence geothermal investment	1
Total	**4**
Answers could include: • habitat disruption – establishing a geothermal resource will require the removal of habitats. By doing so, it must not compromise the continuity of the organisms displaced • water consumption – water used in the production of geothermal energy must not compromise the surrounding ecosystems of communities that are also reliant on this water • noise pollution – construction and operation of the geothermal plant may produce noise that impacts local communities or wildlife, impacting day-to-day activities and animal breeding pattens • induced seismicity – geothermal operations may induce seismic activity due to the pumping and extraction of water. Consideration needs to be given to the impact of community infrastructure due to possible seismic activity.	
Accept other relevant answers.	

(d) Outline **one** political **or** economic reason why some countries or regions with significant resources of geothermal heat do not invest in geothermal energy production. (2 marks)

Description	Marks
Identifies a political or economic reason	1
States how the stated reason prevents investment in geothermal energy	1
Total	**2**

Answers could include:

Political reasons
- development being prioritised in other areas of the country
- political pressure groups campaigning against geothermal power
- political policies in favour of other forms of power generation.

Economic reasons
- lack of financial resources to cover the high capital cost
- sufficient sources of cheaper power being available to meet national need
- potential power generating areas may be too far from locations of power demand to make transmission economic.

Sample answers:

Political – political pressure from alternative energy resource companies. Governments or political parties may be influenced by political donations from existing energy companies not to invest in geothermal power

Economic – high investment costs. Significant upfront investment is required to build a geothermal power station. Many countries are unable to justify this expense.

Accept other relevant answers.

Question 17 **(12 marks)**

(a) Outline how the following attributes of an ore body may help determine how the mineral resource it contains may be extracted.

(i) Value of contained resource (2 marks)

Description	Marks
Identifies a mechanism by which the value of a resource may influence the extraction method used	1
States how the specified mechanism may influence decision-making	1
Total	**2**
Answers could include: • mineral resources with a high value may enable extraction by methods with a higher cost of capital, while resources of low value might only be economic by lower-cost extraction methods such as near-surface open-cut mining • high-value mineral resources can be mined using faster and larger-scale methods because their value allows more waste rock to be moved in accessing the ore.	
Accept other relevant answers.	

(ii) Location of the ore body (2 marks)

Description	Marks
Identifies a mechanism by the location of the ore body may influence the extraction method used	1
States how the specified mechanism may influence decision-making	1
Total	**2**
Answers could include: • a mineral resource located deeper than c.100 m below the ground (and potentially even shallower) will need to be extracted by underground mining accessed via a shaft or underground drive. Otherwise, the cost of removing the overburden to access the ore may exceed the value of the ore itself • a mineral resource located far from a city or port would usually need to be processed or concentrated onsite to make it economic to transport it to users because the cost of transport is directly proportional to the weight or volume of material moved and the distance it needs to be transported.	
Accept other relevant answers.	

(b) State **one** benefit of these surveys for the:

(i) local Indigenous community. (1 mark)

Description	Marks
States a benefit of the survey for the Indigenous community	1
Total	**1**
Answers could include: • identification of significant heritage sites and/or artifacts • increased cultural and historical understanding of the area surveyed.	
Accept other relevant answers.	

(ii) mining company. (1 mark)

Description	Marks
States a benefit of the survey for the mining company	1
Total	**1**
Answers could include: • may clarify sites to be avoided in planning and building mine infrastructure • may meet compliance requirements imposed as a condition of a mining licence.	
Accept other relevant answers.	

(c) State **two** ways a company could communicate with all members (Indigenous and non-Indigenous) of the local community near a planned mine site to support positive long-term relations. (2 marks)

Description	Marks
For each method of communication (2 x 1 mark)	
States a suitable method of communication with the community to support positive long-term relations	1
Total	**2**
Answers could include: • hold regular community meetings • consult regularly with community leaders • employ cultural advisors to engage with the local community • prioritise employing community members • develop education and training programs for local people.	
Accept other relevant answers.	

Question 17 (continued)

(d) Outline **two** environmental **or** economic factors, other than Indigenous heritage and community relations, that should be considered before a mining company commences operations. (4 marks)

Description	Marks
For each factor (2 x 2 marks)	
Identifies an environmental or economic factor	1
States the importance of the environmental or economic factor	1
Total	**4**

Answers could include:

Environmental
- presence of endangered species onsite – endangered species within the mining area may restrict mining areas or require additional monitoring
- impact on the local water systems – before mining, understanding water availability, water runoff and the impact that drawing large amounts will have on ecosystems must be considered.

Economic
- transport cost of resource – isolated mining operations will need to invest more money into transport costs, reducing the economic viability of the resource
- workforce costs – isolated mining operations must factor in the expense of accommodation and transporting workers to the site, reducing the economic viability of the resource.

Accept other relevant answers.

Question 18 **(12 marks)**

(a) Calculate the following using the data above:

(i) total number of ounces extracted between 2015 and 2022. (1 mark)

Description	Marks
430 000	1
Total	**1**
Total extracted ounces = (5 x 50 000) + (3 x 60 000) = 430 000	
Note: As the units are specified in the question, this information does not need to be appended to the answer.	

(ii) ounces of gold added to the resources between 2018 and 2019. (2 marks)

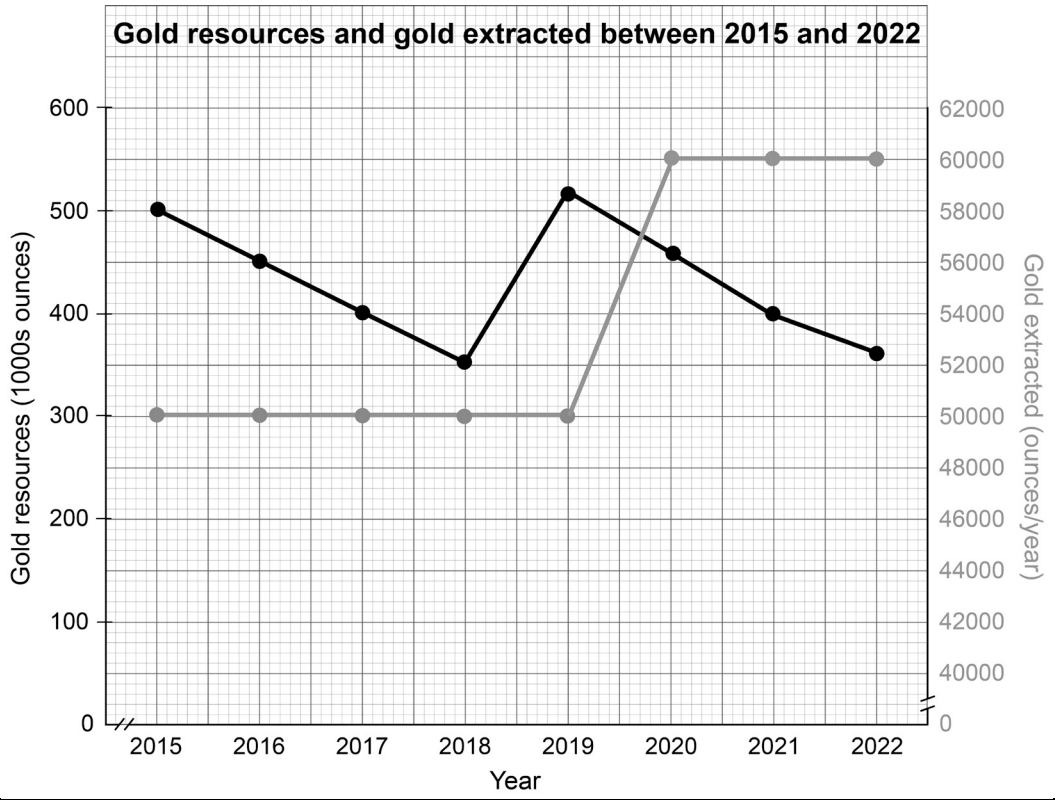
Description	Marks
Calculates the change in stated resource as 170 000 ounces	1
Recognises the gold extracted over this interval also needs to be accounted for and calculates total gold added to resource as 220 000 ounces	1
Total	**2**
Change in stated resource = 520 000 – 350 000 = 170 000 ounces Gold extracted = 50 000 ounces Total gold added to resource = change in resource + gold extracted = 170 000 + 50 000 = 220 000 ounces	
Note: As the units are specified in the question, this information does not need to be appended to the answer.	

Question 18 (continued)

(b) Using the grid provided, draw a line graph showing variation over the eight years of data provided for each of the measured gold resources and gold extracted. (6 marks)

Description	Marks
Gold resources plotted accurately and at an appropriate scale	1
Gold extracted plotted accurately and at an appropriate scale	1
Appropriate title	1
Separate Y-axes used for gold resources and gold extracted so that both datasets are displayed effectively a single graph	1
Axes labelled correctly and with units	1
Legend included	1
Total	**6**

Answers could include:



(c) Explain how geological sampling could lead to an increase in the measured gold resources over time. (3 marks)

Description	Marks
geological samples are analysed and assayed for gold	1
results can be used to find new deposits	1
newly discovered mineralisation can be added to current resources	1
Total	**3**

Sample answer:

Geological sampling, such as diamond drilling, will be analysed for gold using chemical assay techniques. If this analysis returns favourable results, existing resource estimates or models can be increased based on the location and grade of the assay results.

Accept other relevant answers.

Question 19 **(13 marks)**

(a) On the basis of the graph shown above:

(i) state the relationship between the two data sets plotted. (1 mark)

Description	Marks
States a valid relationship observed between the datasets	1
Total	**1**
Answers could include: • deuterium anomaly and CO_2 concentration correlate (change together) over time • when CO_2 concentration is lower, deuterium ratio is more negative • when CO_2 concentration is higher, deuterium ratio is less negative.	
Accept other relevant answers.	

(ii) identify **one** trend or pattern shown by the data over time. (1 mark)

Description	Marks
Identifies a trend or pattern present in the data shown over time	1
Total	**1**
Answers could include: • general increase in CO_2 concentration between 20 000 years and 140 000 years • general decrease in relative variation in Deuterium/Hydrogen ratio between 20 000 years and 140 000 years.	
Accept other relevant answers.	

(b) Explain how scientists would go about extracting and analysing material from ice cores to generate the data shown. (4 marks)

Description	Marks
ice core is collected from ice sheets using ice drills	1
sample is analysed for isotope ratio of hydrogen	1
gas is collected from bubbles trapped in the ice	1
gas is analysed for composition to include CO_2 concentration	1
Total	**4**
Sample answer: Ice cores are collected from suitable sites on the Antarctic ice sheet. These cores are sub-sampled and the isotope ratio of hydrogen in the water is measured on a sensitive mass spectrometer. Gas is collected from bubbles trapped in the ice and subjected to spectroscopic composition analysis to measure the content of CO_2 and other components. These measurements are compared with each other through time to assess relationship.	
Accept other relevant answers.	

Question 19 (continued)

(c) Outline how a natural process could result in change over time in:

(i) atmospheric CO_2 concentration. (2 marks)

Description	Marks
Identifies a relevant natural process	1
States how chosen process can cause measurable change in the CO_2 concentration of the atmosphere over time	1
Total	**2**

Answers could include:

- heating and cooling of global surface ocean waters
- prolonged increase in volcanic activity e.g. flood basalt volcanism
- organic sequestration of carbon e.g. in coal or limestone
- increased erosion and weathering of ultramafic rocks.

Sample answer:

Changing sea surface temperature produces natural variability of CO_2. The solubility of CO_2 is higher in colder water, so during periods of lower global temperatures when the surface waters of the ocean are colder, more CO_2 will be absorbed from the atmosphere, while during hotter periods the sea will absorb less CO_2 so levels of the gas in the atmosphere will rise.

Accept other relevant answers.

(ii) the ratio of heavy and light isotopes of hydrogen or oxygen in rain or snow. (2 marks)

Description	Marks
Identifies a relevant natural process	1
States how chosen process can cause measurable change in isotope ratios of hydrogen or oxygen in rain or snow over time	1
Total	**2**

Answers could include:

- evaporation of water vapour from the ocean
- precipitation of rain or snow from a cloud
- accumulation of significant high-latitude ice sheets.

Sample answer:

Water precipitating as snow in polar regions tends to be enriched in lighter isotopes of oxygen and hydrogen in comparison to ocean water. If large volumes of snow build up in polar ice sheets over time, this measurably increases the abundance of heavier isotopes of oxygen and hydrogen in the remaining ocean water. Because rainfall is derived from evaporation of ocean water, this enrichment will also cause rain to become correspondingly enriched in heavier isotopes.

Accept other relevant answers.

(d) Explain why scientists might be interested in records of the natural fluctuation of atmospheric CO_2 over geological time. (3 marks)

Description	Marks
CO_2 is a greenhouse gas	1
correlation of CO_2 variation with changes in temperature over geological time can help understand how global climate responds to greenhouse forcing	1
this may help scientists understand how global climate may change in the future	1
Total	**3**
Sample answer: Greenhouse gases, including CO_2, are a factor in Earth's global climate system. Understanding natural fluctuations in greenhouse gas levels in our atmosphere and oceans can help scientists understand and model how greenhouse gas emissions now, and in the future, may affect the global climate system.	
Accept other relevant answers.	

Question 20 **(10 marks)**

(a) State **two** decisions that could be made to reduce water use associated with public infrastructure such as parks, sports fields and landscaped public spaces. (2 marks)

Description	Marks
For each decision made to reduce water use (2 x 1 mark)	
States a decision that could be made to reduce water use	1
Total	**2**
Answers could include: • replace grass on sports fields with artificial turf or alternative surfaces that do not require watering • replace non-waterwise plant species (e.g. roses) with native or other drought-tolerant plants requiring less water • schedule watering of public parks and green areas to avoid hot periods of the day.	
Accept other relevant answers.	

(b) Outline **two** factors that affect the sustainability of an identified natural source of drinking water. (4 marks)

Description	Marks
For each factor affecting sustainability of the natural water source specified (2 x 2 marks)	
Identifies a factor relevant to the sustainability of the identified natural source of drinking water	1
States how the chosen factor influences sustainability of the water source	1
Total	**4**
Answers could include: • recharge rate (or equivalent e.g. rainfall, snowfall, river flow, groundwater inflow) • pollution • saltwater upflow • evapotranspiration • evaporation from open water surface • water storage capacity. Sample answer: Two factors affecting the sustainability of rivers as a source of drinking water could be the rate of rainfall in the river catchment and the density of vegetation in the river catchment. River water is ultimately sourced from precipitation, so sustainability of water use is limited by the amount of rainfall across the river catchment. Dense vegetation across a river catchment may slow the rate at which precipitation enters the river, reducing the peak flow level of the river but increasing the length of time it takes for water to flow through the river and reach the sea. This may extend the period over which drinking water can be extracted from the river.	
Accept other relevant answers.	

(c) Explain how a specific technological solution can be applied to supplement the natural supply of drinking water for a city or town. (4 marks)

Description	Marks
Identifies a specific relevant technological solution	1
States possible source/s of the water to supplement the natural supply	1
States that the water provided by the technological solution is treated	1
States how the drinkable water is distributed	1
Total	**4**

Answers could include:

- desalination plants
- reuse of treated wastewater – with or without the intermediary step of aquifer recharge
- rainwater or dew harvesting, i.e. the method cited does not need to be a modern industrial technology; low-tech solutions could be the basis of a valid answer.

Sample answer:

Drinking water could be supplemented by using treated wastewater such as recycled grey water. Grey water from domestic or light industrial use (including laundry, dishwashing, irrigation run-off or baths and showers) is collected at a treatment site, where it is filtered to remove particulate material and sterilised. Treated water may be further purified and can then be piped or otherwise redistributed for human use.

Accept other relevant answers.

Question 21 **(12 marks)**

(a) Describe **one** positive and **one** negative impact of volcanic eruptions for life on Earth. (4 marks)

Description	Marks
Positive effect	
States a positive effect of volcanism for life on Earth	1
Outlines how the identified effect is positive for life	1
Subtotal	**2**
Negative effect	
States a negative effect of volcanism for life on Earth	1
Outlines how the identified effect is negative for life	1
Subtotal	**2**
Total	**4**

Answers could include:

Positive effects
- ashfall, which contains beneficial nutrients, can increase soil fertility and plant growth
- high heat flow near the surface can produce geothermal hot springs exploited as a source of warmth
- heat flow and sulphide-rich exhalations around mid-ocean ridges can support deep sea biological communities.

Negative effects
- erupted lava and/or ash can smother or burn biological communities around an eruption
- build-up of gases released by volcanism can reach toxic levels, killing off local wildlife
- major eruption of ash into the stratosphere can cool global temperature for a period of several years, impacting temperature-sensitive biota.

Sample answers:

Volcanic eruptions generate mineral rich rocks like scoria and fine-grained mineral-rich ash and ejecta. The weathering of these materials results in the generation of high-quality arable soils that are a positive effect for agriculture. (positive)

Volcanic products (lava and ash) released by an eruption can smother and/or burn people, plants and animals in the vicinity. (negative)

Accept other relevant answers.

(b) The nature of volcanic eruptions and the corresponding hazards they pose to local people vary in different tectonic settings. Use your knowledge of volcanic hazards to complete the following table: (4 marks)

Tectonic location	Volcano form	Typical volcanic rocks	Geohazards
Hot spot	*Shield (accept Hawaiian)*	Basalt, scoria, obsidian	Poisonous gases and lava flows
Rift	Caldera or fissure vent (Icelandic)	Basalt, scoria, obsidian	*Poisonous gases, Lava flows*
Subduction boundary	*Stratovolcano (accept composite)*	Andesite, pumice, tuff	*Explosive eruptions, lahar, mudflow, ashfall*

Description	Marks
States the correct response	1–4
Total	**4**
Accept other relevant answers.	

(c) Describe **two** methods of monitoring volcanic activity to provide early warning of hazards to local populations. (4 marks)

Description	Marks
For each type of volcanic hazard monitoring specified (2 x 2 marks)	
States the method of volcanic monitoring	1
Outlines how the identified monitoring method provides early warning of eruption	1
Total	**4**

Answers could include:

Methods of volcanic monitoring:
- measuring seismic activity beneath/in the area of a volcano
- measuring changes in composition of gases released by a volcano
- measuring ground deformation or changes in slope angle of a volcano.

Sample answer:

Seismic monitoring can record earthquakes caused by magma rising through fractures beneath a volcano. Such movement of magma near the surface (and corresponding seismicity) often increases in the days leading up to an eruption.

Accept other relevant answers.

Question 22 **(14 marks)**

(a) The boundaries of the basalt unit with all other lithologies are seen to continue straight across the landscape. State what this observation indicates about the style of intrusion of the basalt body. (1 mark)

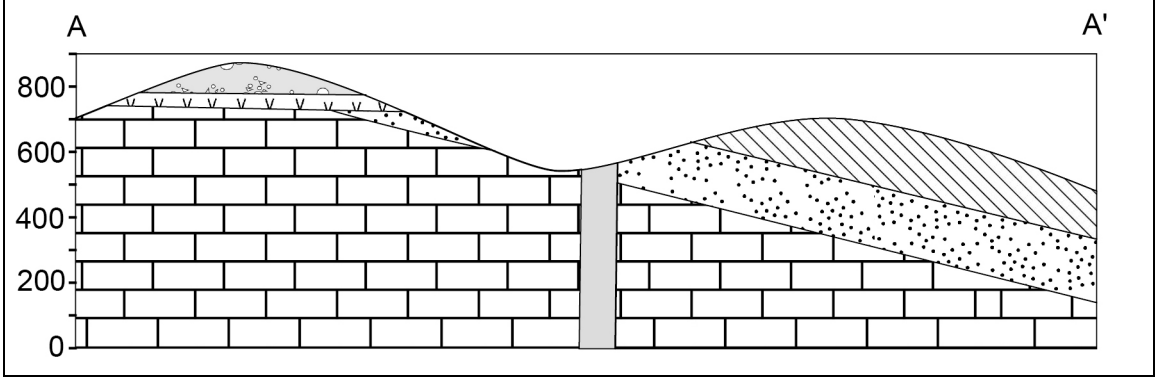
Description	Marks
the basalt is a vertical dike (or dyke) or the contacts of the basalt are vertical	1
Total	**1**
Accept other relevant answers.	

(b) The geologist visits the point marked as Z at the peak of a hill in the area. Name the lithology they would expect to find at point Z. (1 mark)

Description	Marks
mudstone	1
Total	**1**

(c) Construct a cross-section along the line A–A' in the box provided, interpreting geology below the surface down to sea level. Note: to assist you in transcribing strata locations, you may remove page 45 by tearing along the perforations. (6 marks)

Description	Marks
Accurate construction of topography	1
Accurate transposition of geological contacts from the map	1
Volcanics and conglomerate shown as horizontal layers	1
Sandstone and mudstone shown as dipping eastward	1
Basalt shown as a vertical dike cutting all other units it meets	1
Boundary between limestone and sandstone projected accurately beneath the hilltop volcanics	1
Total	**6**



(d) Shallow drillholes are drilled at points X and Y to test the subsurface geology. Both holes start in sandstone and intersect limestone some distance below the surface. Identify which hole would encounter the deeper contact between the two lithologies. (1 mark)

Description	Marks
hole Y	1
Total	**1**

(e) (i) State **one** form of geological evidence they may look for in the field to test these alternative hypotheses. (1 mark)

Description	Marks
States an appropriate form of geological evidence	1
Total	**1**
Answers could include: • evidence of exposure of the upper surface of the volcanic to weathering prior to deposition of the conglomerate* • contact metamorphism of the lower surface of the conglomerate where it is in contact with the volcanic.	
Accept other relevant answers.	
Note: *or any specific evidence implying this condition, e.g. paleo soil development or weathering of the upper volcanic surface, erosion of the upper volcanic surface, the presence of volcanic clasts in the conglomerate etc.	

(ii) Describe how this evidence in part (d)(i) would distinguish between extrusive and intrusive origin for the volcanics. (2 marks)

Description	Marks
States how the chosen evidence relates to the origin of the volcanics	1
States how the evidence would differentiate between intrusive and extrusive origin	1
Total	**2**
Sample answer: Identification of a paleo soil horizon Soils develop over time when rocks are exposed to weathering and biological processes (e.g. plant growth) at the surface. If a paleo soil horizon is present on the top surface of the volcanics, that would mean it had to have been exposed for a substantial period before the conglomerate was deposited – so the volcanics must have been a surface flow.	
Accept other relevant answers.	

Question 22 (continued)

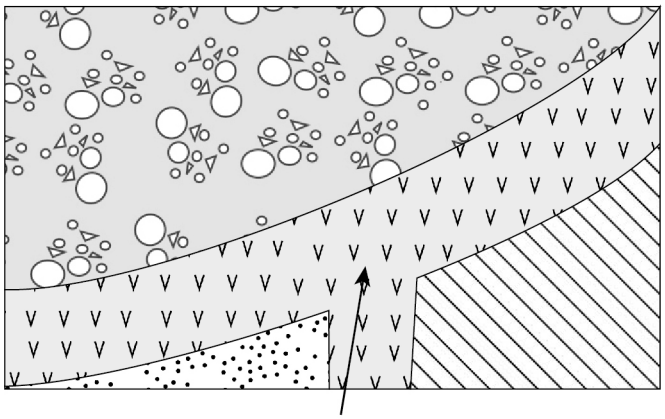
(f) Describe **or** draw a labelled sketch map illustrating the geological relationships that might be observed between these lithologies in the area marked as 'Unknown' if the geologist's hypothesis is correct. (2 marks)

Description	Marks
States or shows volcanics and basalt would be shown as the same lithology	1
States or shows that volcanics and basalt would connect up with one another and/or have no intervening contact	1
Total	**2**

Answers could include:

Characteristics of the supposed basalt and volcanics units would be indistinguishable from one another in outcrop and, where the two met, they would be found to connect with one another with no contact or other break present.

or



Accept other relevant answers.

Question 23 **(12 marks)**

(a) Name a non-renewable mineral or energy resource and state a geophysical or geochemical technique that could be used in early-stage exploration for your chosen resource in a new area. (1 mark)

Description	Marks
States a geophysical or geochemical technique suitable for early-stage exploration of the chosen resource named	1
Total	**1**

Answers could include:

For coal:
- seismic reflection survey
- aerial gravity survey.

For petroleum (oil and/or gas):
- seismic reflection survey
- aerial gravity survey
- chemical analysis of groundwater.

For uranium:
- aerial radiometric survey
- soil geochemistry
- chemical analysis of groundwater.

For iron ore:
- aerial gravity survey
- aerial magnetic survey
- soil geochemistry.

For gold:
- aerial gravity survey
- aerial magnetic survey
- soil geochemistry.

Accept other relevant answers.

Note: No mark awarded for stating the resource, but technique specified must be applicable to exploration for the chosen resource.

Question 23 (continued)

(b) State the rock property that your chosen exploration technique in part (a) is measuring and describe how this technique in part (a) would differentiate between areas where your chosen resource is present and areas where it is absent. (3 marks)

Description	Marks
States an appropriate rock property relevant to the chosen technique	1
States how the technique would respond to the presence of the chosen resource	1
States how the response would differ in the absence of the chosen resource/in a barren region	1
Total	**3**

Answers could include:

- for seismic reflection survey – density contrast between lithological layers
- for gravity survey – density
- for magnetic survey – iron content of rock (or magnetic intensity)
- for soil or geochemical surveying – chemical composition of rock.

Sample answers:

For seismic reflection survey applied to search for petroleum – seismic reflection surveys record the distribution of rocks below the surface from the reflection of seismic energy from the boundaries between rock layers of different density. If the seismic reflections received indicate the presence of an anticline (upward fold) in sedimentary rocks or other structures that might act to trap migrating hydrocarbons, the area may be worth investigating further. If no potential trap structures are present, hydrocarbons cannot have accumulated, and the area will be barren.

For soil geochemistry applied to search for gold – soil geochemistry measures the elements present in samples of soil. Because soil is partly made up of residual material left by the weathering of the underlying rock, if gold-bearing rocks are present beneath the surface, soil samples may have an anomalously (unusually) high content of gold in comparison to background levels. If no gold anomaly is detected across an area, it is unlikely significant gold resources are present.

Accept other relevant answers.

(c) Explain how your chosen technique in part (a) would be applied in an exploration program **or** survey to test for the presence of the resource. (4 marks)

Description	Marks
States the measurement equipment required for the chosen technique	1
States the deployment process required for a survey	1
States the physical scale and spatial resolution of a survey	1
States the different stages of the program or survey	1
Total	**4**

Sample answer:

Geochemical soil sampling
Soil is collected from shallow holes dug by hand or with an auger at sites spaced in a grid across the area of interest. In a reconnaissance survey like this, sample sites may be spaced anywhere from a few tens of metres to several kilometres apart, depending on the survey budget and the size of the area to be covered. Samples are collected in individual bags over a period of a few days to a week or more and transported en-masse to a geochemical laboratory facility for analysis, where depending on the specific elements of interest, their chemical makeup may be analysed by x-ray diffractometry or by dissolving in acid and analysed on a mass spectrometer.

Accept other relevant answers.

(d) If a potential resource was identified in the initial exploration, outline **two** further methods that could be applied to assess the scale or potential value of the resource. (4 marks)

Description	Marks
For each specified method (2 x 2 marks)	
Identifies a mineral exploration method that could be applied to assess the chosen resource	1
States how this method would be applied or could be of value in assessment of the scale or value of the specified resource	1
Total	**4**

Answers could include (depending on the resource chosen):

- exploration drilling and assaying (accept specific use of RC, diamond or air core drilling)
- electromagnetic (EM) survey
- field mapping
- test mining and/or bulk sampling of ore
- 3D seismic survey.

Sample answer:

Following positive initial results, the area identified as possibly mineralised could be tested by a series of drillholes to collect rock samples from beneath the surface. These samples could be chemically tested to answer key questions including whether the mineral of interest is present and, if so, how deep it is located beneath the surface.

Accept other relevant answers.

Question 24 **(14 marks)**

(a) Using an example, explain how a specific tectonic process can lead to metamorphism of pre-existing rocks. (3 marks)

Description	Marks
Names a relevant tectonic process	1
Names a protolith and resultant metamorphic rock from this process	1
States how the process produces metamorphism	1
Total	**3**
Answers could include: Compression at convergent boundaries results in realignment and/or parallel growth of crystals during regional metamorphosis. This realignment and aligned growth will create the layered fabric of a phyllite or other foliated rock from a shale protolith.	
Accept other relevant answers.	

(b) Describe **two** identifying characteristics for each of the following metamorphic rock types. (6 marks)

Description		Marks
Rock Type	**Identifying Characteristics**	
Phyllite	exhibits foliation or a silvery appearance due to mica crystals that are too small to see by the naked eye	1–2
Marble	exhibits recrystallised interlocking calcite crystals and an increased crystal size reacts with acid producing bubbles	1–2
Gneiss	exhibits dark and light banding, complete recrystallisation with feldspars and amphiboles exhibits course grain size, augens or other porphyroblasts	1–2
	Total	**6**
Accept other relevant answers.		

(c) Explain why a metamorphosed basalt would be expected to contain a greater variety of minerals than a metamorphosed quartz sandstone at an equivalent metamorphic grade. (3 marks)

Description	Marks
basalt is a mixture of minerals with varied chemistry	1
quartz sandstone contains mostly silicon dioxide (quartz)	1
the more varied chemical building blocks derived from the basalt can be recombined into a greater variety of minerals than the simple quartz sandstone	1
Total	**3**
Sample answer: Basalt contains mafic minerals with varied chemistry, including complex silicates like pyroxenes and feldspars. Quartz sandstone contains mostly silicon dioxide (quartz). Recombined into new minerals during metamorphism, the complex chemical components can form a wider variety of mineral structures than the sandstone, which can essentially only grow new quartz crystals.	
Accept other relevant answers.	

(d) Describe **one** way in which metamorphism could contribute to the development or enrichment of an economic mineral resource. (2 marks)

Description	Marks
States a metamorphic process or consequence that could contribute to an economic mineral resource	1
Outlines how that process results in an economic mineral resource	1
Total	**2**

Answers could include:

- release of water during dehydration reactions
- creation of fluid pathways through alignment of minerals
- production of heat by exothermic reactions
- release of metal ions due to breakdown of their host mineral.

Sample answer:

Hydrothermal fluids released by dehydration reactions can dissolve potentially valuable metals from country rock and transport those metals as ions to a location that allows precipitation via a pathway such as a permeable fault. Where these fluids cool or depressurise, the contained metals will precipitate as sulphides or other minerals and create an area of concentration that could become an ore body.

Accept other relevant answers.

Section Three: Extended answer **30% (30 Marks)**

Question 25 **(15 marks)**

(a) Explain how a specific geological process (one for each resource) can lead to the accumulation or formation of **one** non-renewable energy resource and **one** metallic mineral resource. (6 marks)

Description	Marks
For each resource (2 x 3 marks)	
Identifies a geological process appropriate for the stated resource	1
Outlines the mechanism for accumulation or formation of the stated resource	1
Links accumulation or formation to the creation of a resource deposit	1
Total	**6**

Answers could include:

Non-renewable energy resource

- petroleum – organic rich sedimentary material is deposited in low energy ocean basin environments. Further deposition results in further burial of the sediments, increasing pressure and temperatures. The sediments undergo chemical reactions to form hydrocarbons. These hydrocarbons are trapped beneath layers of fine-grained sediments
- coal – deposition of organic material in swampy, anoxic environments. Prolonged accumulation leads to burial and compression of this partially decayed organic matter, where heat and pressure chemically convert this material to peat and lignite. The continued, cyclic deposition of this organic matter will result in the development of coal seams.

Metallic mineral resource

- gold – magmatic and hydrothermal activity are associated with many gold deposits. Mineral rich fluids that are derived from magmatic activity are capable of dissolving and carrying gold and migrate through fractures away from the source rock. As pressure and temperatures decrease, the gold is precipitated out of solution and deposited in rock fractures
- iron ore – early photosynthetic organisms release oxygen as a waste product, which reacts with soluble Iron Fe^{2+} in the ocean, forming insoluble Fe^{3+}, precipitating as layers onto the ocean floor. During times of low iron availability, silica rich layers such as chert are deposited. Banded iron formations occur due to the cyclic deposition of alternating layers of iron rich sediments and silica rich materials.

Accept other relevant answers.

(b) Given the processes identified in part (a), compare the tectonic settings in which each of your chosen resources might develop. (5 marks)

Description	Marks
For each tectonic setting (2 x 2 marks)	
Identifies a suitable tectonic setting for the stated resource	1
Outline characteristic of the tectonic setting that influences the stated resource	1
Subtotal	**4**
Comparison	
Compares tectonic settings i.e. similarities or differences between tectonic setting of chosen resources	1
Subtotal	**1**
Total	**5**

Answers could include:

- petroleum – continental margins, including rift zones and valleys, leading to the development of sedimentary basins
- coal – tectonic activity resulting in basin formation. This includes uplift and subsidence of continental crust and collisional zones
- gold – commonly associated with convergent plate boundaries involving magmatic activity
- iron ore – Archean basins, stable continental cratons that have not undergone significant tectonic processes.

Accept other relevant answers.

(c) Following the initial accumulation of the resources specified in part (a), outline how subsequent geological processes might lead to the concentration or dispersal of each of your chosen resources. (4 marks)

Description	Marks
For each of the resources specified (2 x 2 marks)	
Identifies a process of concentration or dispersal for stated resource	1
States how the process concentrates or disperses the resource	1
Total	**4**

Answers could include:

- petroleum – migration of hydrocarbons from the source to the reservoir is critical to the concentration of petroleum resources. Hydrocarbons will migrate to porous rocks, such as sandstone, and become trapped. As the migration continues the concentration of the resource increases
- coal – ongoing diagenesis (burial and compaction of sediments) will transform peat into coal of various quality. During this process, excess water is removed and increased heat is applied to the material. If this process is prolonged over a wide area, the concentration of anthracite (high quality coal) may increase
- gold – the continued magmatic conditions and subsequent movement of hydrothermal fluids through rock fractures will result in the ongoing precipitation and concentration of gold in the area
- iron ore – the process of supergene enrichment enables the concentration of iron ore. The movement of meteoric water interacts with iron bearing rocks, leaching iron material into solution and transported through the surrounding rock, concentrating secondary iron minerals such as goethite and hematite.

Question 26 **(15 marks)**

(a) Identify **two** ways in which local changes in the hydrosphere could leave a physical record with the potential to be preserved over geological timescales. (2 marks)

Description	Marks
For each specified way (2 x 1 mark)	
Identifies a valid mechanism by which hydrosphere changes could leave a geological record	1
Total	**2**

Answers could include:

- growth of continental ice sheets preferentially removing light isotopes of oxygen and hydrogen from the oceans
- coral growth as a record of sea level
- laying down of lake sediment varves
- deposition of moraines by retreating glaciers.

Accept other relevant answers.

(b) Describe how scientists could compile a record of change in the hydrosphere pre-dating human history, using **one** of the physical records specified in part (a). (3 marks)

Description	Marks
States a relevant sampling methodology	1
Outlines how the proxy record relates to changes in the hydrosphere	1
Outlines how the proxy record pre-dates human history	1
Total	**3**

Sample answer:

Snowfall that builds the ice sheets in Antarctica and Greenland trap water from the precipitation from the atmosphere over time. This snowfall builds layers that occur regularly roughly following annual seasons and can be much older than human history. The water provides heavy to light isotopic ratios of hydrogen and oxygen that correlate with global ice volume. Global ice volume correlates with average global temperature – cooler temperatures result in larger ice sheets. Ice cores taken from suitable locations can be subsampled at intervals and provide a record of changes in the hydrosphere that pre-dates human history.

Accept other relevant answers.

(c) Describe **two** ways in which climate change has altered the hydrosphere over the past 20 years. (4 marks)

Description	Marks
For each way (2 x 2 marks)	
States a valid way in which climate change has altered the hydrosphere over the past 20 years	1
Outlines how climate change has produced the specified change	1
Total	**4**

Answers could include:

- higher sea surface temperatures leading to changes in oceanic circulation and extreme weather
- additional latent heat in the atmosphere leading to more extreme weather such as drought and flood
- sea level rise coupled with reduction in global ice volume
- an enhanced El Niño-Southern Oscillation (ENSO), Indian Ocean Dipole (IOD) or other general climate circulation system.

Sample answer:

Climate change has increased the global sea surface temperature because of heat exchange from the warmer atmosphere. Warmer water evaporates more readily leading to more moisture in the atmosphere. This additional moisture results in more powerful storms and higher, more intense rainfall.

Question 26 (continued)

(d) Explain the probable impact of future climate change on **two** renewable resources derived from the hydrosphere (including provisioning services, regulating services and supporting services). (6 marks)

Description	Marks
For probable impact on each renewable resource (2 x 3 marks)	
States a renewable resource that could be impacted	1
States a feasible impact on the specified resource	1
States the cause-and-effect relationship between climate change and the specified resource	1
Total	**6**

Answers could include:

Increased heat and climate instability resulting in:

- reduced freshwater availability from unreliable rainfall and loss of glacier meltwater
- water purification services compromised due to eutrophication and drought
- reduction of biodiversity resulting in invasive pests impacting aquaculture
- changing ocean temperatures and/or currents impacting the distribution or viability of a specified fisheries resource.

Sample answer:

Future climate change is predicted to result in large areas of Earth's surface receiving significantly reduced annual rainfall. The combination of warmer temperatures and reduced rainfall will impact freshwater supply to both human populations, agricultural industry and ecosystems. This reduction in water supply would result in conflict, migration, financial impacts and a reduction in biodiversity.

Accept other relevant answers.

Question 27 **(15 marks)**

(a) Given the information provided, identify **three** hazards an earthquake could pose to people living in the proposed apartment complex. (3 marks)

Description	Marks
For each hazard specified (3 x 1 mark)	
Identifies a hazard that could reasonably arise from earthquakes in the setting described	1
Total	**3**
Answers could include: • severe ground shaking damaging buildings and infrastructure • unconsolidated sediments could experience liquefaction during severe shaking, causing damage and collapse of structures • strong ground shaking could trigger landslides • submarine earthquakes or landslides could cause tsunamis.	
Accept other relevant answers.	

(b) Describe **two** types of study that could help understand the magnitude and/or frequency of earthquake events the site may experience. (6 marks)

Description	Marks
For each type of study specified (2 x 3 marks)	
Identifies a study that could help understand the magnitude and/or frequency of earthquake events at the site	1
States methods of data collection that could be undertaken to understand the potential for future earthquake events at the site	1
States how the study provides understanding of potential future earthquake events at the site	1
Total	**6**
Relevant forms of study could include: • trenching of identified faults to study history of past events • evaluation of the historical record of seismic activity in the region • detailed mapping of fault structures in the region • compilation of evidence of seismicity in the local stratigraphic record • long-term (six months or more) passive seismic study to determine background seismicity. Sample answer: Assessment of historic seismicity in the region could provide insight into the frequency, style and magnitude of earthquake events the site may experience. Earthquake events over the past several decades will likely be recorded in one or more seismic monitoring network. Earthquakes pre-dating seismic monitoring (or if the area is remote) may be recorded in old newspapers or historic documents, or even oral histories of local people. Compilation of historical records and potentially interviews would provide a statistical guide to local seismic activity and its impacts.	
Accept other relevant answers.	

Question 27 (continued)

(c) Identify **two** measures that could be taken in the design, construction or operation of the planned apartment complex to mitigate seismic risk. (2 marks)

Description	Marks
For each measure identified (2 x 1 mark)	
Identifies a measure that could contribute to mitigation of seismic risk for an apartment complex	1
Total	**2**
Answers could include: • incorporating elements of earthquake resistance into buildings such as ▪ insulating foundations ▪ steel braced construction ▪ other valid construction features • installing tsunami warning systems • educating residents on best practice procedures for earthquake preparation and response • practising building evacuations • abandoning the project entirely.	
Accept other relevant answers.	
Note: Each discrete specified element of construction and design could be accepted separately as a viable answer.	

(d) Explain how each of the measures identified in part (c) would reduce hazards for occupants of the planned apartments. (4 marks)

Description	Marks
For each measure (2 x 2 marks)	
States details of how the specified measure operates or is enacted	1
States how the operational details provided reduce hazard	1
Total	**4**
Answers could include: Incorporating elements of earthquake resistance, such as seismic insulating foundations, in the design and construction of the apartments would reduce risk to the inhabitants. Rubber piles or damped spring foundations can decouple a building from the ground, reducing the transmission of high-frequency ground shaking to the structure. This reduces the shear stresses placed on the building during an earthquake, making it less likely to experience structural damage. If adequate risk mitigation is not possible by other means, abandoning the planned building project would eliminate hazard issues entirely. If there are no residents, there is no risk of anyone being harmed by earthquakes.	
Accept other relevant answers.	

Published by the School Curriculum and Standards Authority of Western Australia
303 Sevenoaks Street
CANNINGTON WA 6107