AS/A-LEVEL

STUDENT GUIDE

WJEC/Eduqas

Geography

Glaciated landscapes

Tectonic hazards

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About this book

This guide has been designed to help you succeed in WJEC AS and A-level and Eduqas A-level Geography: **Glaciated landscapes** and **Tectonic hazards**.

The **Content Guidance** summarises the key information that you need to know to be able to answer the examination questions with accuracy and depth. In particular, the meanings of key terms are made clear. You will also benefit by testing your knowledge with knowledge check questions, and noting the exam tips, which provide further help in determining how to learn key aspects of the course.

The **Questions & Answers** section includes sample questions similar in style to those you might expect in the exam. There are sample student responses as well as detailed commentary giving further guidance in relation to what exam markers are looking for in order to award top marks. You should refer to the answers and comments only after you have attempted the questions.

The topics covered in this guide are:

Eduqas A-level Component 1: Changing landscapes and changing places

- Section A: Changing landscapes: Glaciated landscapes

Eduqas A-level Component 3: Contemporary themes in geography

- Section A: Tectonic hazards

WJEC AS Unit 1: Changing landscapes

- Section A: Changing landscapes: Glaciated landscapes
- Section B: Tectonic hazards

WJEC A2 Unit 4: Contemporary themes in geography

- Section A: Tectonic hazards

The formats of the different examination papers are summarised in the table below.

Specification and paper number	Total time for section	Total marks for section	Structured questions	Extended response/essay
Eduqas A-level Component 1: Section A Glaciated landscapes	**50 min** in a paper lasting 1h 45 min	41/82	**Two** compulsory structured data-response questions Marked out of 13	**One** question from a choice of two Marked out of 15
Eduqas A-level Component 3: Section A Tectonic hazards	**40 min** in a paper lasting 2h 15 min	38/128	None	**One** question from a choice of two Marked out of 38
WJEC AS Unit 1: Section A Glaciated landscapes	**40 min** in a paper lasting 2h	32/96	**Two** compulsory structured data response questions Marked out of 16	None
WJEC AS Unit 1: Section B Tectonic hazards	**80 min** in a paper lasting 2h	64/96	**Three** compulsory structured data response questions Marked out of 22, 24 or 18	None
WJEC A2 Unit 4: Section A Tectonic hazards	**38 min** in a paper lasting 2h	20/64	None	**One** question from a choice of two Marked out of 20

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Content Guidance

Glaciated landscapes

The glacial system

Formation of glacier ice

Glacier ice is formed primarily from compacted snow, with smaller contributions from other forms of precipitation, such as hail or sleet, which freeze directly on top of or inside the glacier.

Granular snow (density 0.19 $g\,cm^{-3}$) is increasingly compacted to form **névé** or **firn**. Further pressure transforms firn into glacier ice (density 0.9 $g\,cm^{-3}$), which is then deformed by further pressure to flow outward (in the case of an ice sheet/cap) or downward (for a glacier) by **extrusion flow**. Overall rates of transformation from snow to ice can be as little as 100 years in some temperate areas, but can take up to 4000 years in Antarctica.

Exam tip

Always use appropriate geographical terminology and use a geographical dictionary to define specialist terms.

Inputs and outputs of the glacier system

Glaciers can be viewed as open systems, with inputs, outputs and interactions with other systems, such as the atmosphere, oceans, hydrosphere and landscape. Within systems there are various stores, in this case the glaciers and other ice masses, and energy and materials are transferred by flows/fluxes.

Exam tip

A study of systems is a vital part of the specification. Learn the key diagram (Figure 1).

The glacier system is driven by inputs of energy from the Sun, which evaporates water from the oceans to create air masses. These can produce precipitation (snowfall, sleet and hail). Mass enters the system in the form of snowfall and rock debris (inputs). As this mass generally occupies an elevated position in the Earth's gravitational field, this mass has **potential energy**, which is expended as the glacier flows downslope. The energy expended is used to warm or melt ice, and then must be dissipated from the system in the form of heat and water (outputs). As this is going on, potential energy is turned into work, transferring ice and rock from highland areas towards lower levels and the oceans.

Knowledge check 1

Why can glaciers be classified as an open system?

Knowledge check 2

What are the main outputs in a glacier system?

Glacier mass balance

Mass balance is defined as the gains and losses of the ice store in the glacier system.

Accumulation results from direct snowfall or other precipitation, and from icefalls, blown snow and avalanching from slopes above the glacier surface.

The snow and ice are then transferred down-valley by glacier movement until they reach lower areas where they are lost to the system by processes collectively known as **ablation**.

Ablation results from melting, evaporation (sublimation) or the breakaway of ice blocks and icebergs at sea level (known as **calving**).

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At the same time, there is input of rock debris supplied by weathering and erosion of slopes above the glacier. This is transported and eventually deposited as another glacier output in the form of moraines and other deposits.

As Figure 1 shows:

- there is more accumulation than ablation in the upper part of the glacier
- there is more ablation than accumulation in the lower part of the glacier
- the glacier's **equilibrium point** is where accumulation and ablation balance each other out

Glaciers are dynamic systems as the ratios of inputs to outputs vary considerably between glaciers, and continually over both short-term and longer-term timescales.

Knowledge check 3

What is the glacial budget?

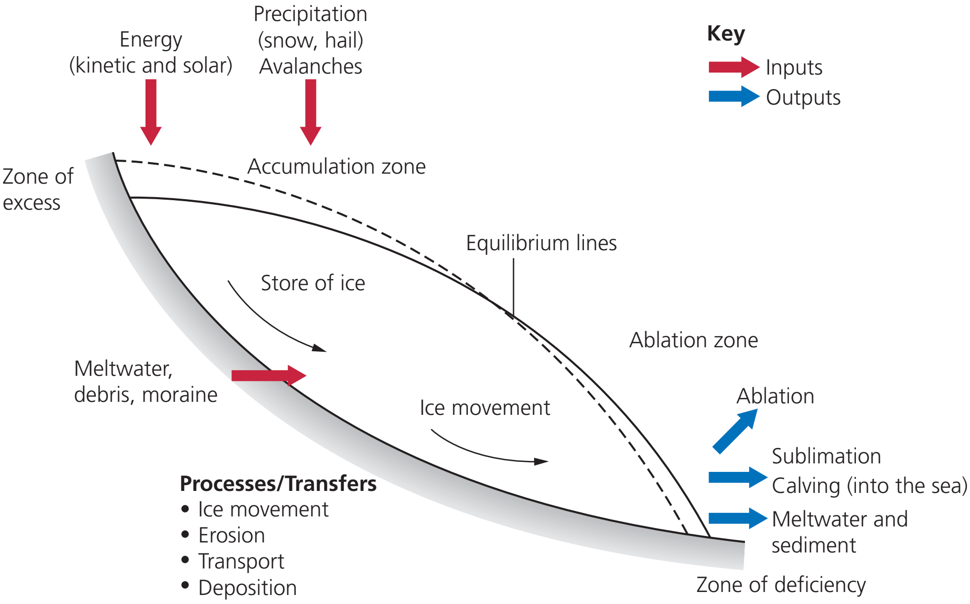

Figure 1 The glacier mass balance as a system

Short-term changes

Figure 2 shows the following theoretically:

- If accumulation exceeds ablation, the usual situation during the winter, the glacier increases in mass, i.e. a **positive regime** for the glacier budget. This causes the glacier to grow and therefore to **advance** at the snout.
- Conversely, in summer when there is more ablation than accumulation (because of rising temperatures), the glacier budget has a **negative regime**. This causes the glacier to shrink, thin or **down waste**, and therefore the snout begins to retreat.
- If the annual **net** balance is zero, i.e. there is no difference between accumulation and ablation, in theory the glacier is likely to be at a **stillstand**.
- Even within the timespan of the annual budget, the changing regimes (which cause changes in annual net balances) are likely to have some visual impact on the size of the glacier mass.

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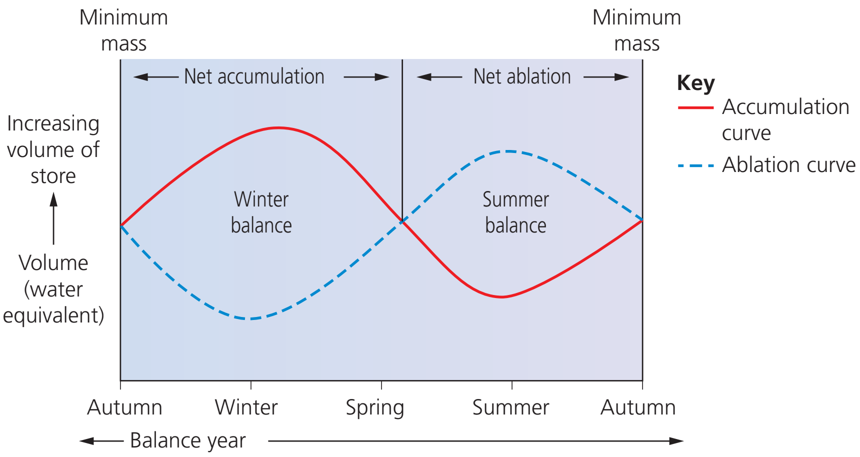

Figure 2 The annual mass balance of a typical glacier. Note: the mass balance year runs from autumn to autumn when ice masses are generally at their lowest volume

Longer-term changes

In the longer term the situation is far more complex. The annual net balance can be calculated for each year and trends can be summarised by looking at readings over a period of time, usually a decade. From these longer-term trends the **cumulative net balance** can be calculated.

The Bench Mark Research Project carried out by the United States Geological Survey (USGS) measures longer-term changes in the mass balance of four benchmark glaciers: Gulkana and Wolverine in Alaska, South Cascade in Washington State and, most recently, Sperry in Montana (since 2005). These glaciers are called benchmark glaciers because the aim of the project is to measure each glacier's response to climate change by providing long-term records of both annual and cumulative mass balance trends. Both the fieldwork methodology and analyses use common strategies to enable comparisons to be made between the glaciers, which were chosen as a representative sample of glaciers from across the USA (see Figure 4 on page 13).

It is these longer-term trends that determine the 'health' of the glacier, and whether it will significantly advance or retreat. Currently it is estimated (largely using data from polar orbiting satellites) that 75% of the world's ice masses are experiencing 'rising trends' in their net negative balances, almost certainly as a result of short-term climate change (the average global increase in surface temperature was 0.6°C in the last century, with rises of more than 2°C in the crucial areas of Greenland and the Antarctic Peninsula). The Arctic and east Antarctica ice sheets are thinning and melting, which has led to increasing concerns over the impact of global rises in sea levels.

The concept of equilibrium

Glaciers are constantly changing due to variations in parts of the system. As a result, there are three types of equilibrium (Table 1).

Knowledge check 4

Define cumulative net balance.

Exam tip

Become practised at calculating means and totals of mass balance measurements in tables. They may be a feature of your AS exam.

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Table 1 Three types of glacier equilibrium

Type of equilibrium	Description	Example
Steady-state equilibrium	Changes in accumulation and ablation do not vary much from the long-term average conditions.	The glacier adjusts in winter and summer due to changes in temperature, but the average size stays the same.
Metastable equilibrium	The glacier changes from one state of equilibrium to another due to an event causing a change in conditions.	Subglacial volcanic activity increases melting of the ice. When the activity ends there is a new equilibrium, with a reduced glacier.
Dynamic equilibrium	The state of equilibrium changes over a longer timescale than metastable equilibrium.	Climate change, causing increased temperatures, results in ablation being continually greater than accumulation. The glacier reduces in mass, leaving areas of land uncovered.

Positive and negative feedback in the glacier system

Feedback effects are those that can amplify *or* diminish changes, for example in glacial mass balances.

Positive feedback can amplify small changes in a glacier budget in a variety of ways, such as:

- **Snow and ice cover**. Small increases in snow/ice cover raise the surface albedo (reflectivity), so more solar energy is reflected back into space — leading to further cooling, which could lead to further snowfall, and therefore to further ice cover.
- **Melting of snow/ice cover** by climate warming from greenhouse gases (e.g. emissions of CO_2) decreases albedo, and methane is emitted as permafrost melts. The seas warm up, which causes calving of ice sheets, leading to even more losses of snow/ice cover and surface albedo, so decreasing reflectivity and accelerating further warming and yet further ice loss.

Negative feedback decreases the warming or cooling rates, which of course has an impact on ice cover. Increases in global warming will lead to more evaporation, and therefore more cloud cover. This is further enhanced by industrial pollution. Increasingly cloudy skies reflect more solar energy back into space, so diminishing global warming. Less intense global warming means the thinning of glaciers should decelerate and ultimately decrease.

Ice sheet dynamics can themselves disrupt the **thermohaline circulation**. Warming water in the Arctic disrupts the **Arctic conveyor** and this means less warm water from the Gulf Stream is drawn north to northwest Europe. This onset of colder conditions could lead to global cooling, with less ice melt, possibly an advance in glacier snouts and also diminishing numbers of icebergs calving into the ocean.

Feedback mechanisms are important in sustaining the trend towards warmer or colder conditions. These result in glacial and interglacial periods, as well as shorter-term stadials and interstadials, such as the **Medieval Warm Period** and the **Little Ice Age**, both of which occurred in historic times and the impacts of which are well documented.

Exam tip

The term negative feedback does not mean it has a detrimental effect. It is negative because it reduces the impact of the original change. Feedback is one of the key concepts within systems geography. Make sure you understand it.

Knowledge check 5

Explain what is meant by the 'thermohaline circulation'.

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Summary

- The glacial system includes inputs, outputs, stores and transfers of energy and materials.
- Mass balance is the result of gains and losses of the ice store in the glacier system.
- Changes occur to the inputs to and outputs from a glacier over short- (annual) and long-term timescales.
- The equilibrium point is reached when losses from ablation are balanced by gains from accumulation.
- The glacial budget is the annual growth and retreat of the glacier resulting from accumulation and ablation. A positive regime causes a glacier to grow, whereas a negative regime causes it to retreat.

Climate change and glacial budgets

Causes of climate change through the Quaternary Ice Age

Many scientists say that we are currently living in the most recent Ice Age, the **Quaternary**, which began around 2 million years ago with the onset of global cooling and **ice-house** conditions following the end of the Tertiary period. Recent theories suggest that plate tectonics created suitable conditions to 'kick start' the Ice Age by positioning Antarctica as an isolated continent at the South Pole.

The Quaternary period is divided into two epochs of geological time, although many researchers argue that a third epoch should be added, called the **Anthropocene**, which is completely dominated by the impact of humans and their activities.

- The **Pleistocene** covers the timespan from the beginning of the Quaternary to about 11,500 years ago when the most recent continental glacial ended.
- The **Holocene** interglacial (the period in which we now live) is similar climatically to previous interglacials, but is distinctive for the beginning and growth of human civilisation, in particular agriculture and industrialisation.

Knowledge check 6

What are the proposed start dates for the Anthropocene epoch?

Figure 3 summarises the characteristics of the Pleistocene — on a geological timescale it can be regarded as a single ice age, but as the figure shows there were multiple periods of glacials (colder **ice-house** conditions) and interglacials (**greenhouse** or warmer conditions).

Figure 3 also shows numerous fluctuations within the major glacial/interglacial cycles, operating at a number of timescales. These shorter periods of intense cold are called **stadial** periods, with shorter periods of relative warmth, known as **interstadials**. Recent data from ice core sampling suggest that some of the more severe fluctuations in temperature actually occurred quite abruptly. Eventually, a fluctuation in the climate will be significant enough for a glacial threshold to be reached. Further climatic change will then be reflected in changes to the glacier budget.

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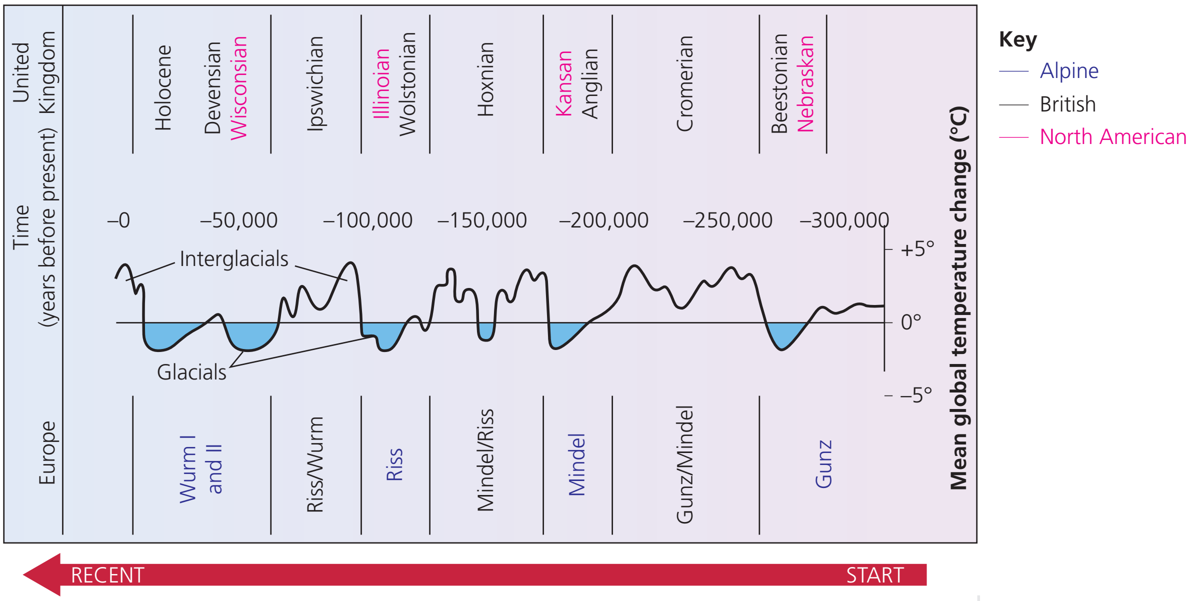

Figure 3 Ice age chronology

Causes of longer-term glacial/interglacial cycles

Long-term changes in the Earth's orbit around the Sun are currently seen as the primary cause of the oscillations between glacial and interglacial conditions. The **Milankovitch theory**, based on **orbital/astronomic forcing** of glacial periods, takes into account three main characteristics of the Earth's orbit:

- **Eccentricity** of the orbit. It changes from being more elliptical to more circular and back again over a period of around 100,000 years, thereby changing the amount of radiation received from the Sun (this is considered to be the dominant factor).
- **Axis tilt** varies from 21.8° to 24.4° (currently the tilt is 23.5°) over a timescale of around 41,000 years. This changes the sunshine intensity at the poles and therefore the seasonality of the Earth's climate. The greater the tilt, the greater the difference between summer and winter.
- The Earth '**wobbles**' on its axis (just like a spinning top), changing the point in the year at which Earth is closest to the Sun (**axial precession**), over a 21,000-year cycle. This causes long-term changes to when different seasons occur along the Earth's orbital path.

The three orbital cycles can combine to minimise the amount of solar energy reaching the northern hemisphere during summer (leading to cooler summers overall).

Milankovitch's theory is supported by the fact that glacials seem to have occurred at regular intervals of approximately 100,000 years. However, the actual impact of the combined orbital changes on solar radiation amount and distribution is small — probably only enough to change global temperatures by between 0.5°C and 1°C.

To explain the larger temperature changes of up to 5°C that were required for the vast expanses of ice to form, or to melt, we have to look at climate **feedback mechanisms**.

In conclusion, many scientists view Milankovitch cycles as a possible trigger for major ice-house–greenhouse changes or even as a good 'pacemaker' during each cycle, but climate feedback mechanisms are needed to sustain the drive towards either colder or warmer conditions that have caused the glacial and interglacial periods (see page 9).

Possible explanations for shorter-term fluctuations

As can be seen in Figure 3, both glacial and interglacial periods have fluctuations within them, with frequent warming (interstadials) and cooling (stadials) periods. As well as the combinations of effects in the Milankovich cycles, a number of factors have been cited for these shorter-term fluctuations.

Solar forcing

Solar energy varies depending on the number and density of sunspots (dark spots on the Sun's surface caused by intense magnetic storms). Reliable records indicate a number of cycles of sunspot activity that vary in length, including 'the 11-year sunspot cycle'. A longer period with no sunspot activity, known as the Maunder Minimum, occurred between 1645 and 1715, at the height of the Little Ice Age. The preceding Medieval Warm Period has been linked to more intense sunspot activity. Although variations in solar radiation caused by sunspot activity is only 0.1% and is not, by itself, enough to explain the climate fluctuations, some scientists suggest that around 20% of twentieth-century warming may be attributed to solar output variation.

Volcanic causes

Violent volcanic activity can alter global climate as a result of global dimming. Eruptions with a high VEI (volcanic explosivity index) of >4 eject huge volumes of ash, sulfur dioxide, water vapour and CO_2 into the atmosphere (volcanic aerosols), which are distributed around the globe by high-level winds. In 1815, Tambora in Indonesia ejected 200 million tonnes of SO_2 into the atmosphere. In the following 2–3 years recorded temperatures were 0.4–0.7°C lower, resulting in short-lived global cooling.

Historical changes in the glacial budget: the Little Ice Age

The Little Ice Age was the longest glacial oscillation in historical times. This was preceded by the Medieval Warm Period in the mid-fourteenth century. Over much of the globe most of the period between AD 1350 and 1900 was slightly colder, perhaps on average between 1.0°C and 2.0°C, than at present. However, between AD 1550 and 1750 there was a period of very cold conditions — the Little Ice Age — which occurred globally.

Proxy records, such as those from historical documents and paintings, add detail to our knowledge of past climate and its impacts. For example:

- There was widespread abandonment of upland farms in Scandinavia and Iceland.
- Many glaciers in Europe readvanced down-valley, because the Little Ice Age was a period of predominantly positive net mass balance. These advances left prominent terminal moraines when the glaciers subsequently retreated, but this often occurred at different dates/times around the world.

Exam tip

Explaining longer-term climate cycles is complex. Learn the facts thoroughly and accurately assess the evidence. Causality is complex.

Knowledge check 7

What is global dimming?

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- Arctic sea ice spread further south, with polar bears frequently seen in Iceland.
- Rivers in the UK and lowland Europe, and New York harbour, froze over.

As with many medium-timescale stadials and interstadials, there is not one simple causal explanation. There is a definite link with sunspot activity — with periods of intense sunspot activity coinciding with warmer periods, and the Maunder Minimum (no sunspot activity — see above) with the coldest period in the Little Ice Age.

Some glaciologists see the Little Ice Age as the beginning of a new stadial and argue that it was the CO_2 emissions and sooty fumes from the onset of the Industrial Revolution that triggered recent warming, halting the Little Ice Age.

However, many scientists believe feedback loops are the key influence in the triggering of the stadial. Changes to the thermohaline circulation seem to be a probable factor — the diversion or blockage of the North Atlantic warming system made areas in the northern hemisphere much colder and therefore subject to glacier advance. The problem with this explanation is that the Little Ice Age was a worldwide event.

Seasonal cycles and their impact on the glacial budget

Virtually all glaciers have a positive mass balance in winter, when accumulation exceeds ablation, and a negative mass balance in summer. The prime reason for this is temperature — lower temperatures in winter can generate increased snow accumulation. Conversely, summer conditions with rising temperatures result in considerable ablation, with evaporation from the glacier surface, and meltwater losses. It only takes a series of hard winters or heatwave summers to cause significant variations in annual net balances.

This is the simplified picture but there are many other variables that make the issue more complex, such as the amount of debris that covers the glacier, the height of the glacier, the latitude of the glacier, or the degree of climate warming.

Figure 4 shows how two of the four benchmark glaciers vary, particularly in the range of their seasonal cycles.

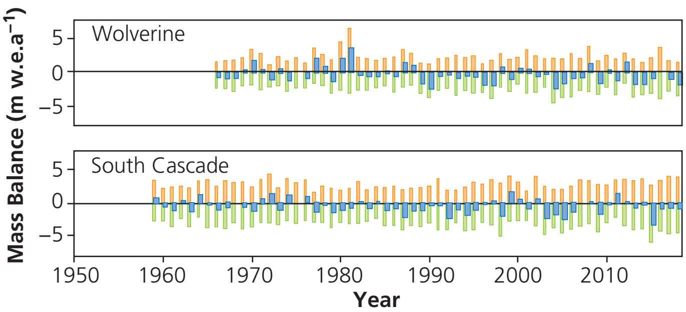

Figure 4 Seasonal cycles of two benchmark glaciers in the USA (see page 8)

Exam tip

Cumulative balance is the overall impact of the totals of annual balances, which are largely negative.

Knowledge check 8

What are benchmark glaciers?

Exam tip

Make sure you can describe the trends shown in diagrams similar to Figure 4.

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Summary

- Long-term changes are called glacials and interglacials, while short-term fluctuations are called stadials and interstadials.
- Long-term changes in the Earth's orbit around the Sun may cause or trigger major changes, but climate feedback mechanisms are probably needed to sustain the drive towards colder or warmer conditions causing the glacial and interglacial periods.
- Other causal factors of short-term fluctuations include solar forcing and volcanic eruptions, and their associated feedback mechanisms.
- Causes of changes in the glacial budget through historical time are complex but may include sunspot activity, the Industrial Revolution and changes to the thermohaline circulation, as well as feedback mechanisms.
- Seasonal changes are mainly the result of temperature, which causes accumulation in winter and ablation in summer.

Glacier movement

Cold-based and warm-based glaciers

The **thermal regime** of a glacier has a major impact on glacier movement, the operation of glacial processes and the landforms that are subsequently produced.

Glaciers have traditionally been divided into warm-based (temperate) glaciers, such as those found in the alpine and sub-Arctic areas (also known as wet glaciers), and cold-based (polar) glaciers.

- **Cold-based glaciers** occur in high latitudes, particularly in Antarctica and Greenland. The average temperature of the ice is usually well below 0°C as a result of surface temperatures as low as −20°C to −30°C, so the accumulation of heat from geothermal sources is not great enough to raise the temperature at the base of the glacier to 0°C, as the ice may be up to 500 m thick. There is relatively little surface melt in the very short and cool polar summer, so little meltwater percolates downwards. The glacier is permanently frozen to its bed, so there is no debris-rich basal layer.
- Outside the polar region, for example in high-altitude areas, most glaciers are the **warm-based** temperate type. The temperature of the surface layer fluctuates above and below melting point, depending on the time of year, whereas the temperature of the rest of the ice, extending downwards to the base, is close to melting point. Because of increased pressure of overlying ice, water exists as a liquid at temperatures below 0°C, causing the basal ice to melt continuously. The effects of pressure, geothermal energy and percolation of meltwater all contribute to prevent the glacier freezing to its bed. The glacier has lots of debris in its basal layers, and significant subglacial depositional features. Figure 5 summarises the contrasting temperature profiles of the two types of glacier and the key temperature controls within a glacier.

Knowledge check 9

What is the 'pressure melting point'?

Knowledge check 10

Outline the differences in the temperature profiles of cold- and warm-based glaciers (use Figure 5).

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Questions & Answers

About this section

The questions that follow are typical of the style and structure that you can expect to see in the exam papers. Each question is followed by comments that give some guidance about question interpretation. Student responses are then provided, with further comments indicating the strengths and weaknesses of each answer and the number of marks that would be awarded.

You should always make use of examples where appropriate and reference data to support your answers. You can include sketch maps and diagrams where relevant. For AS exams the answers are written in the examination booklet, with the number of lines indicating the level of detail required. When writing in an answer booklet it is important to number your answers in the same way as the examination paper. If you use an extension page you must make a note such as ‘continued on page…’ at the end of the previous page. Remember to number the question on the extension page.

The formats of the different examination papers for this theme are given in the table on page 5.

Glaciated landscapes

Question 1 (WJEC AS format)

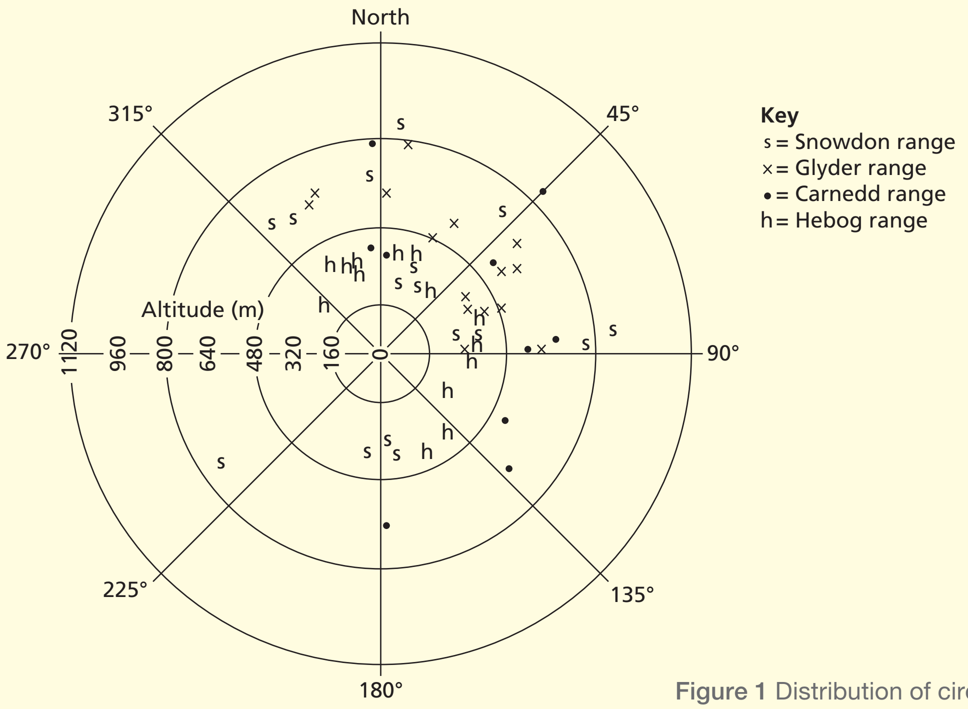

Figure 1 Distribution of cirques in Snowdonia

(a) (i) Use **Figure 1** to describe the distribution of cirques within Snowdonia. (5 marks)

The command word 'describe' is targeting AO3 because it requires you to identify the distinctive features and provide factual detail about the distribution. It is important to use all the information shown in the diagram so your answer should refer to both orientation by compass direction and altitude. As well as the general distribution of all the cirques, differences between the four ranges should also be highlighted. All 5 marks will be awarded for your use of skills in interpreting and analysing the data (AO3).

Student answer

It can be seen in Figure 1 that cirques can be found orientated in all directions. However, the largest number are found facing north to east (90°). This section includes cirques from all four ranges. There are slightly fewer cirques orientated from 315° to north, with cirques from all ranges found there. There are fewer cirques between 90° and 180°, with most from the Hebog range and none from the Glyder range. Only one cirque is found in each section between 180° and 315°, with none from the Glyder or Carnedd ranges.

Apart from three, all the cirques are found at an altitude between 160 metres and 800 metres. The three exceptions are all found close to 800 metres. All the Hebog range cirques are located between 160 metres and 480 metres, while those in the Snowdon range are evenly divided between 160 and 480 metres and 480 and 800 metres. Whilst the Glyder and Carnedd ranges have some cirques found below 480 metres, most are between 480 and 800 metres. There are no cirques below 160 metres.

5/5 marks awarded This is a thorough description of the distribution. A generalised statement about the distribution is then followed up by a more detailed analysis mentioning exceptions to the general pattern where appropriate. It sensibly describes the orientation by compass direction and then refers to altitude, in both cases mentioning differences between the four named ranges. This is better, and less repetitive, than taking each segment of the diagram in turn and describing what is found in it, as it makes it easier to see the overall pattern of distribution. At least five valid points have been made, so full marks for AO3 have been awarded.

(a) (ii) Suggest reasons to explain the distribution of the cirques shown in Figure 1. (3 marks)

In this question you are required to apply your knowledge and put forward plausible ideas about why the cirques are distributed in this way. Therefore all 3 marks will be awarded for AO2. The command word 'suggest' and the 3 marks available indicate that some elaboration, but not a lengthy explanation, is required. The question does not limit you to just one reason.

Student answer

In the northern hemisphere most cirques face between north and east. This is because the Sun is in the south, so the hollows where cirques form are shaded and receive less solar radiation. This results in lower temperatures and so less snow or ice melt, allowing the formation of a glacier over time. The prevailing winds are from the southwest, so less snow is removed but is blown into the cirque, allowing a glacier to build up. The differences in altitude for the locations of cirques may simply be due to differences in the height of the land in each range.

3/3 marks awarded This answer shows a good understanding of the factors that may have influenced the distribution of the cirques in the area. This knowledge has been used to come up with some realistic explanations for the distribution, with a satisfactory level of detail. Although correct, the use of terms such as accumulation and ablation (rather than build up and melting) would have demonstrated a greater level of knowledge of the topic. Perhaps a little more explanation about altitude could be included. However, there are at least three valid AO2 points, for full marks.

(b) Examine the role of bedrock characteristics in influencing glacial erosion and the formation of glacial landforms. (8 marks)

The nature of the bedrock is one of the factors affecting glacial erosion required to be studied by the specification. This question requires you to demonstrate your knowledge and understanding of the factors affecting glacial erosion (AO1). The use of the command word 'examine' shows the need to consider the interrelationships involved with the process of glacial erosion, and to evaluate the role played by bedrock characteristics (AO2). Where possible, the use of relevant examples should support the answer. In this type of question marks are not split evenly between the AOs, with 5 marks being awarded for the demonstration of your knowledge and understanding (AO1), and 3 marks for how you apply this knowledge to the question (AO2).

Student answer

The characteristics of the bedrock in a glacial environment can have an impact on the glacial erosion processes that occur. One characteristic is the bedrock permeability, as the level of permeability will influence the amount of meltwater that may be found at the base of a glacier. If the bedrock is impermeable, meltwater will not be able to pass through it and so more may be found at the glacier base. The water can reduce the friction between glacier and bedrock, allowing for greater movement, which in turn can result in greater levels of erosion.

By influencing the amount of meltwater, this can have an impact on the amount of erosion resulting from plucking that may occur. Where more plucking is present, more debris may be dragged along by the glacier, which can increase the rate of erosion and the formation of large-scale features such as glacial troughs.

As well as permeability, the structure of the bedrock can also be an influencing factor. Where bedrock contains many joints, plucking may occur more readily, which again can increase erosion rates by abrasion as the ice moves.

When a glacier flows over areas of differing bedrock the rate of erosion may increase when the bedrock is softer or weaker. In a glacial trough, greater erosion of the weaker rock may result in a rock basin being formed, which after glaciation may flood to create a ribbon lake such as Windermere in the Lake District. Meanwhile, harder outcrops of bedrock may be more resistant to erosion and will so remain, being shaped into roches moutonnées. If an outcrop of bedrock is large it may result in a crag-and-tail feature, such as the area around Edinburgh Castle.

However, there are a number of other factors that play important roles. The basal thermal regime will influence glacier movement, with warm-based glaciers moving more actively and having a greater potential to erode and create landforms. The thickness of the ice and its velocity can also influence a glacier's erosion potential.

6/8 marks awarded This is a competent attempt to establish the role of bedrock characteristics in glacial erosion. It demonstrates a good level of knowledge by considering bedrock permeability and jointing, and their influence on erosion, as outlined in the specification, and also by mentioning the role they may play in the formation of macro- and meso-scale glacial landforms. Some mention has been made of examples of landforms, but named examples of differences in bedrock would have been beneficial.

It can be seen, therefore, that the characteristics of the bedrock can play an important role in influencing the nature of glacial erosion, and in some cases the type of landform produced. However, the impact a glacier has, and the landforms created, are the result of the combination of a number of factors. Perhaps the most important are those that result in the glacier movement in the first place, as bedrock characteristics will only really play a role once this has occurred.

The impact that bedrock characteristics may have on fluvioglacial erosion rates could also have been considered. This has had some impact on the A01 mark, limiting it to band 2. This answer is awarded 3/5 marks for A01 and 3/3 marks for A02.

Question 2 (Eduqas A-level format)

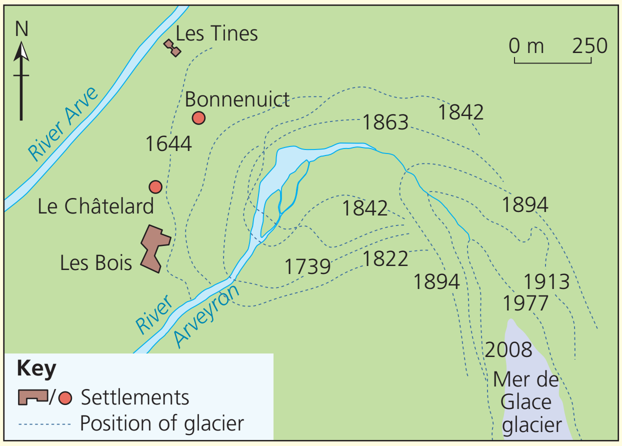

Figure 2 Changing snout position of the Mer de Glace glacier, France

(a) (i) Use **Figure 2** to describe the changes to the Mer de Glace glacier. (5 marks)

The command word 'describe' requires you to provide factual detail about the changes in the glacier, identifying the distinctive features, and so is targeting A03. As a scale is printed on the map your answer should include some measurement of distance when describing the changes. Likewise, use can be made of compass direction. All 5 marks will be awarded for the interpretation and analysis of the diagram (A03).

Student answer

Since 1644 the snout of the Mer de Glace glacier has retreated, so that by 2008 the snout was around 1700 metres further east. At the same time, the area covered by the glacier has greatly reduced, from a having a width of almost 1000 metres in 1822 to 250 metres behind the snout in 2008. Where the snout used to face west, it now faces in a northerly direction.

Whilst the overall change has been a retreat of the snout, this has not been constant throughout that time. From 1739 to 1822 the glacier snout advanced by around 200 metres in some places before retreating back significantly by 1842.

3/5 marks awarded This answer provides a partial analysis of the changes to the glacier, which is supported by the use of measurements and compass directions. The overall trend is noted and then specific changes, such as the period of advance, are described. One improvement would have been to comment on changes in the rate of retreat, for example comparing the distance the snout retreated in the 95 years from 1644 to 1739 with the distance moved in the 31 years from 1863 to 1894. This answer is at the top of band 2, and is awarded 3/5 marks for A03.