Topic 3

Coastal systems and landscapes

Coasts as natural systems

1 Inputs into a coastal system include:

- energy from wind, waves, tides and ocean currents
- sediment either eroded from the local coastal rocks or transported from either offshore or along the coast
- the rock type and structure of the local geology
- sea-level change

Erosional processes such as hydraulic action and abrasion result in erosional coastlines and landscapes as well as eroded material. Attrition alters the eroded material by making it finer and less angular.

Sediment is transported by either water or wind until it reaches a low energy environment where it is deposited.

The outputs from the system are in the form of:

- wave energy dissipated by breaking along the shoreline
- sediment accumulation above high tide level
- sediment moved on to other sediment cells

Systems and processes

2 When the wind starts to blow over the sea's surface there is a certain amount of frictional drag. This energy is transferred to the water and creates ripples. As the wind increases in strength, the ripples get larger until they are large enough to be pushed along by the wind. The movement of the waves is slower than that of the wind and so they increase in size until they become steep enough to break. Swell waves are caused by a combination of wind and atmospheric pressure changes. They travel away from their source areas and reflect the length of time, the wind strength and the distance that the wind has blown over the sea.

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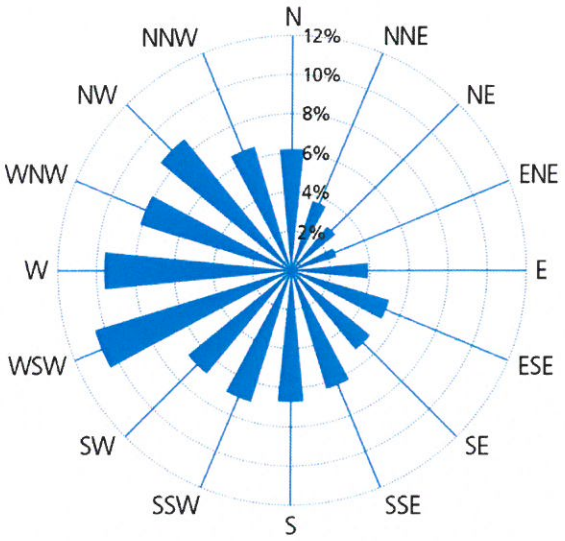

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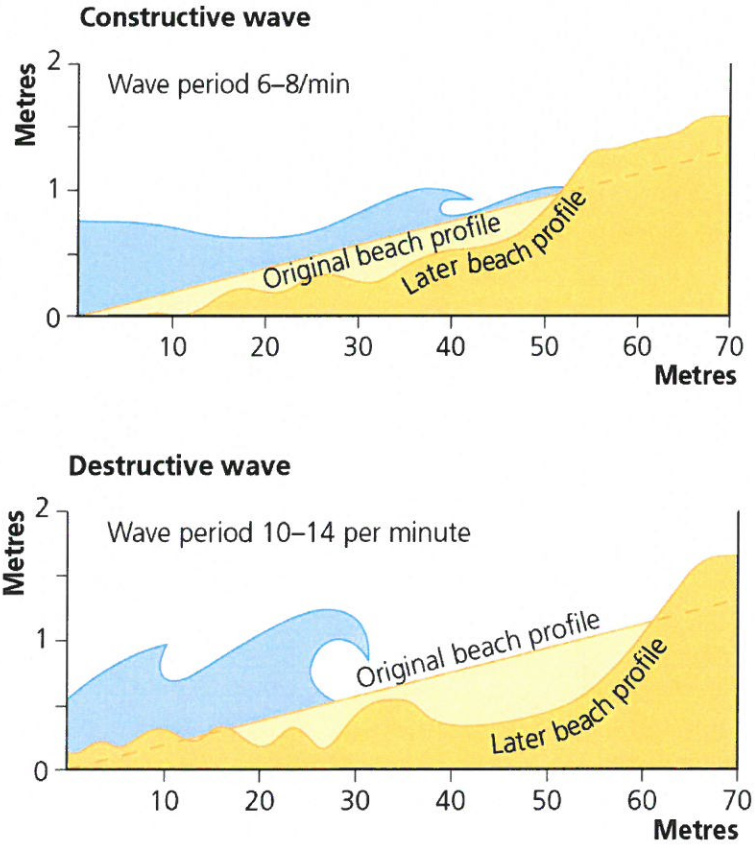

5 Constructive waves have a powerful swash compared to the backwash. The swash carries material up the beach in the turbulent water. Because the backwash is so weak, this material is left on the beach. Although they occur on gently sloping beaches, they cause the beach to steepen.

Destructive waves are plunging. They occur on steeply shelving beaches so that the orbits are not greatly disturbed. The force of the breaking wave is directed downwards and so although it seems

powerful, the swash does not go far up the beach and the backwash is strong. Sand and shingle are taken from the beach and moved offshore.

6 Fistral and Tregurran beaches are open to the west, though Tregurran is also open to the SSW, the most dominant wind direction. It is on these beaches where you are most likely to encounter big waves. Harbour beach is sheltered by Towan Head and although it is sheltered, wave refraction will bring waves onto the shore. It would be good for beginners. Crantock beach is sheltered from all but north to northwest winds. If the wind blew from the NW it may have large waves, but at other times small refracted waves would again make this ideal for beginners.

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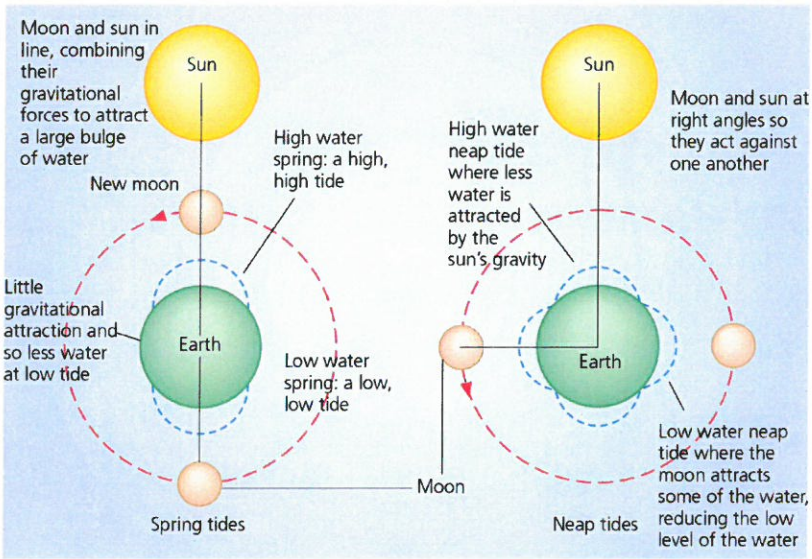


8 The movement of sand and shingle in the nearshore zone by longshore drift has been found to occur in discrete, functionally separate sediment cells. Within these cells the movement of coarser sediment is largely self-contained.

9 One example is Flamborough Head to The Wash (sediment cell 2). It is divided into four sub-cells. The most northerly is Flamborough to the Humber estuary. Most of this consists of boulder clay cliffs to the north and a spit (Spurn Head) to the south. Longshore drift operates, moving sediment from north to south. Sediment leaks out of the sub-cell and crosses the mouth of the Humber to sub-cell 2c, the Lincolnshire coast.

Where Lincolnshire meets the sea is overwhelmingly flat. In the north of the county, the Humber Head Levels and the reclaimed Lincolnshire Marsh are pretty much at sea level, while in the south the Fens give way to salt marshes.

There are 50 km of sandy beaches along the coast. The rivers Great Eau, Lud, Nene, Steeping, Welland and Witham all drain into the North Sea from Lincolnshire, as well as the Humber. Owing to the combined sediment carried by the Humber and the rivers of the Wash, and to the muddy clay sea floor, the waters off Lincolnshire are usually an opaque brown.

10 The main sources are:

- erosion from cliffs
- silt from rivers

- sediment brought along the coast by longshore drift

11 Freeze–thaw weathering is a form of physical or mechanical weathering that induces stress on rocks when water repeatedly seeps into cracks, freezes and expands, eventually causing the rock to break apart. This type of weathering is largely driven by the intensity and frequency of freeze–thaw cycles and the structural properties of the rocks subject to weathering.

On coastlines, this happens above the level reached by waves. Sea water has a lower freezing point than rainwater and so rarely freezes on UK coasts.

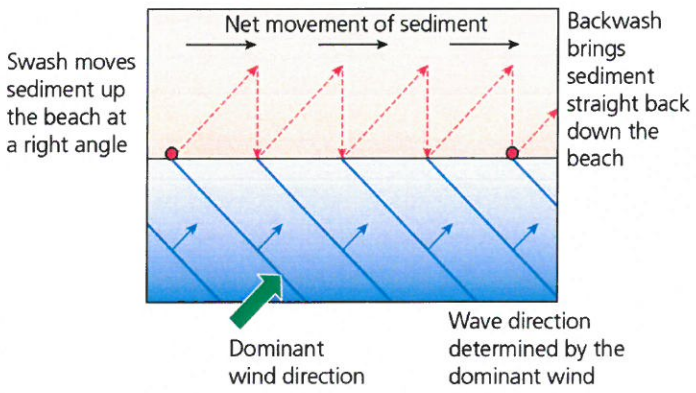
The mild winters of southern and western Britain, contributed to by the relative warmth of the sea water (and the North Atlantic Drift) mean that any form of frost action is rare. North Sea coasts are less affected by the warming influences and so frost action is more common.

12 A common type of mechanical weathering found at coasts is **salt crystallisation**. This is when sea spray wets rock and some of the water soaks into the rocks. When the water evaporates, small amounts of crystalline salt are left behind between the grains of the rock. If this process is repeated, the rock becomes weakened and begins to disintegrate. This granular disintegration means the rock is subject to other weathering and erosion processes.

13 Carbonation is the breakdown of carbonaceous rocks (chalk and limestone) by acidic rainwater. Therefore you need a chalk or limestone coast where there is plenty of rock above the level of the waves. The sea (which is alkaline) does not dissolve limestone except under very special circumstances.

14 An example of slumping has occurred at Overstrand, Norfolk. Slumps happen because of a number of factors. First, marine processes erode and undermine the base of the cliff. Rainwater infiltrates the cliff through unconsolidated boulder clay. The water gathers at the base of the clay where there is a layer of chalk. As more water is added, the clay becomes heavier. A curved slip plane develops and the weight of the saturated clay causes the material to slump along the lubricated slip plane. There is historic evidence of cliff recession as a result of marine erosion and landslides since the late nineteenth century. Cliff retreat has averaged 1.5–2 m per year. A major event in January 1994 resulted in 20 m of recession at the cliff top with debris runout across the beach.

15 In addition to the movements of beach material up and down the foreshore by swash and backwash, material moves along the beach. Sediment is moved along beaches by waves breaking at an angle to the shore. The material is pushed up the beach at an angle to the shore, but when it returns in the backwash, it does so down the steepest gradient, at right angles to the shoreline. Each particle therefore moves in a zigzag fashion.



16 Sand grains bounce or 'saltate' slightly above the surface when blown by the wind. With each bounce, the grains usually reach heights of less than 5 cm above the surface, and move horizontally 5–10 cm. The average distance a grain bounces is the width between the crests of two ripples in the sand. Saltation accounts for about 95% of a sand grain's movement.

Onshore winds will dry out sandy beaches that are exposed at low tide. Sand is blown onshore. In natural circumstances this could produce coastal dunes. Where there is infrastructure along the coastline (roads, railway lines, promenades) then they may be regularly covered by blown sand. This will need to be removed.

Traction involves the 'rolling' of sand grains along the beach surface. It occurs with lower wind speeds or coarse sand.

Coastal landscape development

17 a The base of the cliffs on this headland is attacked by waves. Waves are concentrated on the headland because of wave refraction. The waves can pick up loose material at the base of the cliffs and hurl it at the cliffs. These chip away and undercut the cliff. The sheer weight of the water in waves hitting the cliff sends hammer-blow shocks through the rock, creating openings along lines of weakness such as joints, faults and bedding planes.

As each wave hits the cliff, air trapped in the cliff is compressed. As the wave recedes, this air expands explosively, again opening up weaknesses.

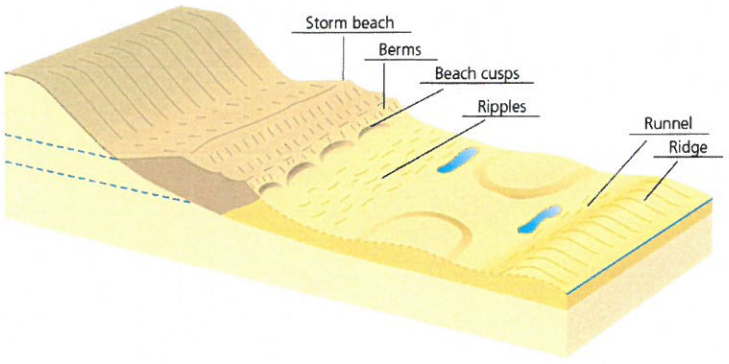
Where lines are opened up, caves appear. If the cave occurs on a headland, then it can cut through the headland to form an arch.

Constant undercutting of the cliff leads to a notch at the base of the cliffs. If this becomes sufficiently deep, the cliff above becomes unsupported and collapses. This leads to cliff recession and the wave-cut platform.

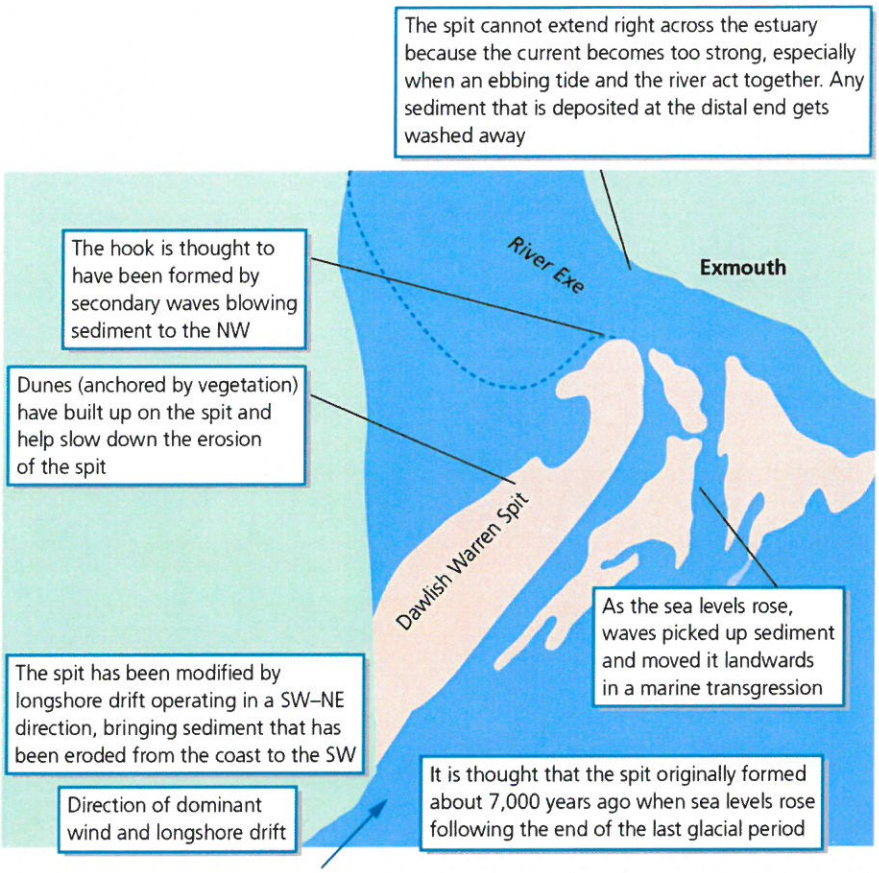
b Stacks are formed when arches collapse. This happens when:

- undercutting of the sides of the arch continues, making it wider and less well supported
- weathering occurs at the top of the arch, making it become structurally weak
- gravity causes the top of the arch to collapse

18 The main features of a beach



19 One example is the spit at Dawlish Warren:



20 Sand dunes are sometimes found at the top of beaches, above the high tide mark, but not every beach has dunes. For dunes to form there must be a supply of sand, a means of transporting it, and somewhere for it to be deposited more quickly than it is eroded.

At low tide, deposits of sand in the inter-tidal zone (between the high and low tide marks) may be exposed and start to dry. The dry grains of sand can then be transported by the wind (by saltation). If the wind blows towards the land, sand will be transported up the beach and beyond the high tide mark.

When the dried sand reaches the top of the beach it can be trapped by debris such as driftwood, dead seaweed or rocks and pebbles. If the sand is not eroded again it may become colonised by small plants, or trap other windblown debris, increasing its size and thus trapping even more sand.

As the dunes grow in size they are able to catch more of the sand blown across them by the wind. This causes the wind speed to lessen and the sand grains are deposited. Vegetation such as marram grass colonises the dunes. Its long net-like roots hold the sand in place and the stems slow down the wind, allowing deposition.

Most dune areas consist of parallel rows of dunes. They increase in age, height and species diversity inland.

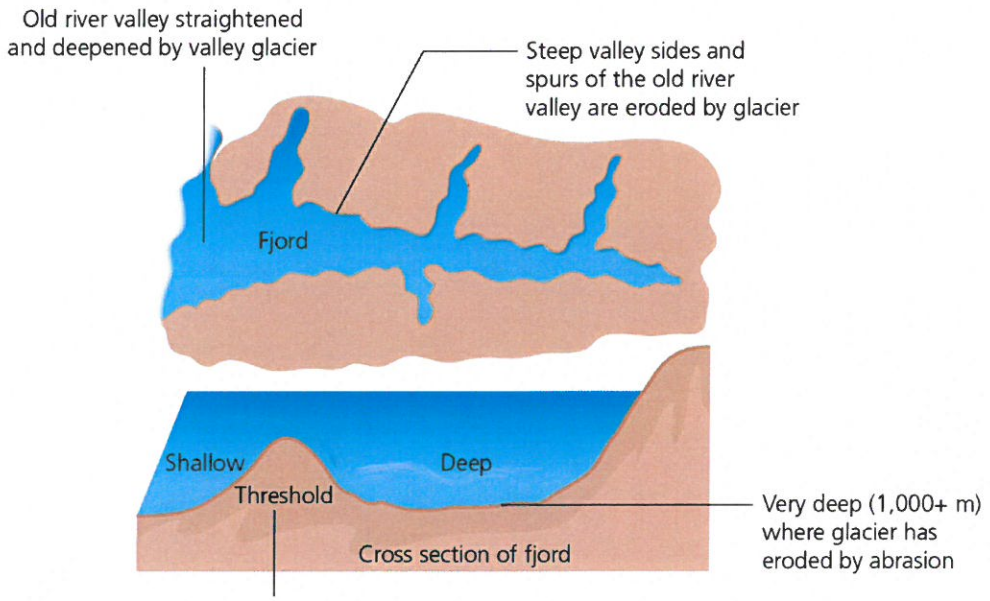
The dunes reach their maximum height where they are fixed. Further inland they become smaller as their source of material is blocked by younger dunes. These become a grey colour from the amount of dead organic matter that is added to the sand.

21 Salt marshes only form in low energy environments where there is shelter from the wind and waves. Depositional landforms such as spits can help provide this shelter. Salt marshes require a large input of sediment, which can arrive from the sea and rivers. The most likely place along a coastline where you will find this sort of sediment input is near a tidal flat. The low gradient of a tidal flat means that any rivers that flow into it will very quickly deposit any sediment they are transporting. At the same time, the periodic flooding of the tidal flat by the tides will deposit even more sediment.

Over time, sediment accumulates and the elevation of the tidal flat increases in a process known as coastal accretion. This reduces the duration of tidal flooding, allowing a small selection of plants to grow on the now developing salt marsh. These plants are halophytic — they love salt — and are capable of surviving underwater for several hours a day. They are often called pioneer species because of their hardy nature, able to live in extreme conditions. These plants, which include species of cordgrass (*Spartina*) and glasswort (*Salicornia*), have several adaptations that not only help them thrive in saline environments but also help aid coastal accretion.

The vegetation traps sediment that is too fine to settle out of water in a salt marsh, building up a muddy substrate. At the same time, the roots help stabilise already deposited sediment, aiding coastal accretion. Pioneer species such as *Spartina alterniflora* are invasive plants that spread rapidly. Once these plants are introduced to a salt marsh, coastal accretion takes place quickly and the elevation of the salt marsh increases greatly. This creates new environments that are submerged by the tide for shorter periods of time, allowing even more species of plants and animals to colonise the salt marsh.

22 Example of a fjord:



Threshold islands mark the area where:
- the snout of the glacier floated and did not erode as much
- glacial load was deposited as terminal moraine

Coastal management

23 Depends on the coastline chosen. Hard defences include sea walls, revetments, diodes, groynes, rock armour, offshore reefs etc.

Goals will be based on reduction of damage balanced with the cost of the scheme.

24 Depends on the scheme chosen. Sustainability will depend on cost/benefits, environmental impacts, success (or otherwise) of the scheme.

Exam-style questions (AS)

1 *Allow 1 mark for each valid point with additional marks for developed points. (3 marks)*

Weathering weakens rocks and makes them more susceptible to erosion. Arches collapse because the tops are weathered. They are far from the reach of marine processes. Biological weathering can include burrowing into clay cliff which gives access to water and increased mass movement.

2 *AO2, AO3: Level 2 (4–6 marks); Level 1 (1–3 marks)*

This is an area of coastal emergence. There are two raised beaches which indicate three periods when sea level remained static. The oldest surface is at the top of the cliffs. Below that is a raised beach backed by cliffs. This was formed as sea levels dropped and then stayed still for enough time to erode the caves and wave-cut notch. Old beach deposits are strewn on the low-angled surface. The sea level dropped again to its present level, eroding a new cliff into the old platform.

3 *AO1, AO2: Level 3 (7–9 marks); Level 2 (4–6 marks); Level 1 (1–3 marks)*

Sea-level change can produce many features along coastlines. We can categorise these features based on how they are formed.

Emergent landforms

Emergent landforms begin to appear towards the end of an ice age and they occur when isostatic rebound takes place faster than a eustatic rise in sea level. Put more simply, the land's height rises faster than the sea's. Emergent features are features of coastal erosion that appear to have developed well above the current sea level. In fact, they developed when the sea *was* at that level and then the sea level changed during an ice age and now they are above sea level.

One such emergent landform is a raised beach. Raised beaches are wave-cut platforms and beaches that are above the current sea level. You can normally find some old cliffs (relic cliffs) too behind these raised beaches with wave-cut notches, arches, stacks etc. along them.

These emergent features no longer experience coastal erosion but they are still weathered, often being weathered biologically, chemically and via freeze–thaw weathering.

Submergent landforms

Submergent landforms are the opposite of emergent landforms. They form when the eustatic rise in sea level takes place faster than the isostatic rebound after an ice age. Basically, the water starts to flood the land and fills up landforms on the land.

One submergent feature is a ria. This is a river valley that has been flooded by the eustatic rise in sea level. Rias are almost exactly like typical river valleys but they have even more water in them. The cross section of a ria is similar to the one you would find for a river in the lower course. The floodplain of the river also gets flooded, altering the cross profile of a ria ever so slightly so that it includes the floodplain.

Another submergent feature is a fjord. Fjords are steeper and deeper variants of rias that are relatively narrow for their size. They have a U-shaped cross profile and are often found in particularly icy sections of the world. They are flooded glacial valleys. In general, fjords are really deep — however, they have a shallow mouth (known as a threshold) as this is where the glacier deposited its load. An example of a fjord is Sognefjord in Norway, which is 1,308 m deep and 205 km long, though its maximum width is only 4.5 km.

The final submergent feature is a Dalmatian coastline. These form in areas of the world where valleys (especially glacial valleys) lie parallel to each other and to the coastline. When the valleys are flooded by the rise in sea level, the tops of the valleys remain above the surface of the sea and appear to be a series of islands that run parallel to the coastline. The best example of a Dalmatian coastline is the one from which they get their name, the Dalmatian coast in Croatia.

4 *AO1, AO2: Level 4 (16–20) marks; Level 3 (11–15 marks); Level 2 (6–10 marks); Level 1 (1–5 marks); Level 0 (0 marks)*

Depends on the example chosen. Good examples include the Sundarbans of India and Bangladesh. Risks include the increased likelihood of encountering cyclones and coastal flooding. On the plus side there are opportunities for eco-tourism, particularly as this is one of the last places on Earth with wild tigers.

Exam-style questions (A-level)

5 *Allow 1 mark per valid point with extra mark(s) for developed points. (4 marks)*

Eustatic sea-level change occurs when the total volume of sea water changes. This can be either because of:

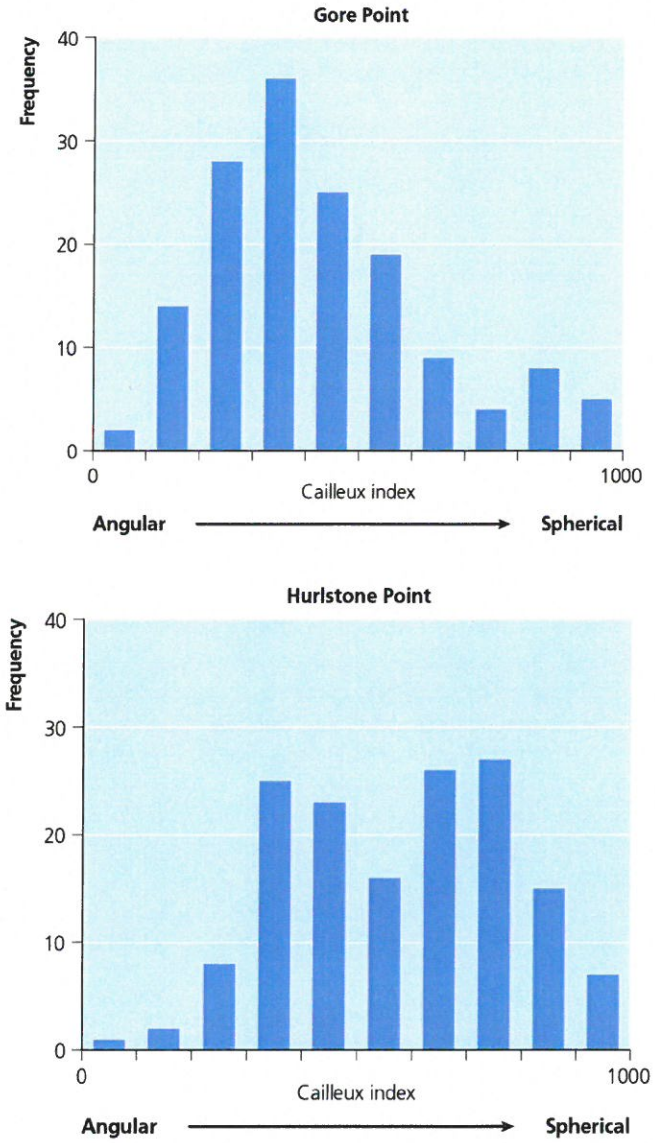
- an interruption of the hydrological cycle, meaning that water is evaporated from the oceans and precipitated on the land where it stays, usually because it falls as snow

Or because:

- volume can change because of thermal expansion/contraction. If the oceans warm up, they will expand and have a greater volume. If they cool, the opposite happens.

6 AO3: Level 2 (4–6 marks); Level 1 (1–3 marks)

a



Hurlstone shows both a greater amount of sorting and greater roundness. The pebbles have been affected by transport (longshore drift) and attrition from West to East.

b Spearman's rank

7 AO2, AO3: Level 2 (4–6 marks); Level 1 (1–3 marks)

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8 AO1, AO2: Level 4 (16–20 marks); Level 3 (11–15 marks); Level 2 (6–10 marks); Level 1 (1–5 marks); Level 0 (0 marks)

There are a variety of ways of approaching this question.

One example is that globalisation leads to increasing world trade. In order for this to be enabled there need to be deep-water ports to handle ever-larger ships. These ports take up a lot of land, most of it sterile regarding wildlife and so not very sustainable. Some ports, e.g. Liverpool, do include nature reserves which are usually out of bounds to the general public and so go largely undisturbed.

Another example is the creation of prawn hatcheries in Bangladesh and Myanmar to supply increased demand for luxury foods in NICs. These necessitate the removal of coastal mangrove forests and leave the coastline susceptible to cyclone damage.