CHAPTER 5 ACTION OF WAVES

Objectives

After studying this chapter, students should be able to:

- state the differences between agents of wave action such as waves, tides and ocean currents.
- describe the process involved in wave erosion.
- describe the characteristics of landform features formed out of coastal erosion and deposition.
- describe the types of coasts.

5.1 Waves

Waves constitute one of the active agents of denudation that wears away the surface of the Earth. Waves can be regarded as turbulent movement of ocean and sea water due to the blowing of wind over the surface water. The blowing of wind over the ocean surface causes the water to move or surge towards the coast in ripples. Waves are largely initiated by strong winds, and perhaps the most powerful agent of marine erosion. Waves are of two types: *constructive wave* and *destructive wave*. A constructive wave is that which drives strong forward movement of water and debris up the beach. A destructive wave is that whose back movement of waves and debris is much powerful than the forward movement. A constructive wave breaks at the rate of 10 or less per minute while a destructive wave breaks at the rate of 10 or more per minutes. *Tides* are the alternative rise and fall of sea surface water two times a day. *Ocean currents* are the movements of sea water towards a definite direction. Waves, tides and ocean currents all

work together in ensuring the shape and form of erosion activities along the sea shore.

5.2 Processes of Wave Erosion

As mentioned earlier on, the processes of wave erosion is largely influenced by the action of sea waves. Sea waves are generated by strong winds that blow over the ocean and sea surfaces. It is the action of these winds that results in a series of undulating (rise and fall) swells called waves which in turn makes the ocean water to move forward in the direction of the winds. The waves become stronger, swifter in response to the increasing wind strength, duration and distance (also known as *fetch*). Waves continue their movements long after they leave the area in which they were initiated. As they approach the shore or coastline, their speed becomes reduced and they are curved or refracted by the frictional effect of the sea floor which later destroys the circular movement of the water particles.

The above describes how waves operate along the coast or shoreline. Hence, there are processes that guide the action of waves. These include:

1. Hydraulic Action
2. Corrasion or Solution
3. Corrosion or Abrasion
4. Attrition

1. **Hydraulic Action:** This process often occur, when in their forward surge, waves splashes against coastal rocks such that joints and crevices are created in the rocks. This result in the compression of the air contained in the rocks. With the retreat of waves, the compressed air later expands the cracks and makes them to break

away. The repeat occurrence of this process is largely responsible for the breaking and shattering of the rocks as the cracks become bigger.

2. **Corrasion or Solution:** This action is usually common in limestone regions and coasts where the solvent action of ocean or sea water acts on calcium carbonate or chalk rock which leads to their disintegration or reduction. Their disintegration is due to their dissolving easily in water.
3. **Corrosion or Abrasion:** This occurs when the load (broken rock fragments) carried by ocean/sea waves are hurled or rubbed against the base of a cliff or coastal rock thereby resulting in undercutting which eventually leads to the falling of larger rock pieces. The eroded material is later carried back into ocean by backwash of the waves. The load used as tools consists of rock pieces, pebbles, shingles, boulder and sand.
4. **Attrition:** This is the wearing down of the load which as mentioned earlier consists of boulders, pebbles, shingle and sand. The wearing down is caused when pieces of the load are knocked or rubbed against each other by the breaking waves. This action is responsible for the presence of relatively fine pieces of fragments which are well polished that are found along the shore.

These processes, collectively determine the nature and extent of wave erosion. In addition to this, is the fact that certain factors influence the extent of wave or coastal erosion. The factors include; the impact of wave energy, the nature of rocks found along the coast, and the extent at which coastal rocks are exposed to wave attack. All these factors largely determine the rate of coastal erosion including human interference in the form of coast protection.

5.3 Wave Transport

Ocean waves and tides constitute the medium through which materials such as rock fragments, pebbles, boulder, shingle, stones, mud, etc are transported or moved. Much of the sea load is brought to the sea by rivers in the form of sediments or soil particles. Some may be in form of rock fragments or materials brought down through fluvial (river) action. The movement of water courses along the coast is called **LONGSHORE DRIFT**. It usually occurs where waves approach the shore or coast in a diagonal form and the backwash (retreat) of the waves takes place at right angles to the shore. By this action, the load is moved in progression along the coastline to further assist in other processes of wave erosion.

5.4 Landform Features Produced by Waves or Coastal Erosion

There are several landform features produced by coastal erosion and they include:

1. Cape
2. Bay/Headlands
3. Cliff/Wave-cut platforms
4. Caves
5. Stack
6. Arch
7. Stumps
8. Geo and Gloups
9. Overhang and Undercut

1. Capes and Bays

A cape is an extension of land moving into the sea. They are steep-sided and consist of hard rocks which are highly resistant to wave erosion. Typical examples include Cape Verde, Cape Blandew, Cape Palma, Cape

Mesurado all in Africa). A bay is a wide, open curry indentation of the sea or lake into the land e.g. Hudson Bay in Canada. Both cape and bays are formed when rocks of varying resistant along the coast are eroded irregularly by waves. Where soft and hard rocks are exposed, the soft rocks are worn easily than the hard rocks. Bays are otherwise called headlands. Where these hard and soft rocks appear alternatively, the soft rocks are worn back resulting in the formation of landform features called inlets or coves. Bays are also called promontories. A way of differentiating these landform features is by simply identifying the rock composition. Land form features with soft rocks are the inlets, coves or bays while the ones with harder rocks are called headlands, promontories or capes.

Fig. 5.1: Cape

Characteristics of Landforms

(i) They are made of hard rocks that are highly resistant to erosion.
(ii) They are generally steep-sided and they face the ocean or sea.
(iii) They project or extend into the sea or ocean.

Bays or Headlands

(i) They are inlets made of relatively soft rocks.

(ii) They are less steep than capes.

Fig. 5.2: Wave-cut platform

2. Cliffs and Wave-Cut Platforms

These are twin platforms produced by wave-erosion. However, a cliff is a high, steep rock facing a coast. A cliff has its land rising steeply and an appreciable height inland. Most cliffs result from wave erosion. Their attributes or characteristics depend largely on the nature of the rocks, and the force of the sea waves that produces them. Cliffs can also be formed when waves induces the cutting of a notch along the coast at about high-tide level. With further erosion, the notch becomes well developed and a cliff becomes noticeable. Where there are uniform rocks along a coast, straight cliffs develop. On the other hand, where resistant rocks are found alongside soft rocks, an indent cliff is formed. Steep cliff occurs when their rocks which are in layers slope downwards. At the same time, there could be cliffs whose rock layers slope seaward and blocks of rock are loosened by erosion and easily fall into the sea. Most coasts in West Africa are made up of cliffs.

Wave-cut platforms occur at the base of the cliffs which remain as the cliff recedes landwards under the effect of the sea waves. The platform that is created as a result of the falling of the cliff is called wave-cut platforms. They are usually gentle in slope.

Fig. 5.3: Cave

Characteristics of Cliff

(i) It is steep-sided with some appreciable height.

(ii) It is usually characterized by gentle slopes called wave-cut platforms that extents towards the sea.

Characteristics of Wave-cut Platform

(i) It slopes gently towards the sea and its surface is usually covered with rock debris.

(ii) When a wave-cut platform attains a certain width, it is covered by shallow water which reduces wave action so that the rate of coastal collapse may slow down.

On a general note, wave-out platform are usually found alongside with cliffs. In soft rocks, the profile of the platform is concave. The platform is fronted by an accumulation of shingle and sand. Examples of cliffs include the chalk cliffs of the English Channel, Beachy Head, Seven Sisters in Cuckmere, White Cliffs of Dover all in the United Kingdom. A typical example of a wave-out platform is found in Strand Flat along Western Norway.

3. Cave, Arch, Stack and Stump

A cave is a hole produced in the regions of local weakness at the foot or base of a cliff. It is funnel-like opening at the base of a cliff face. A cave naturally develops where there is a weakness in the rocks. It is largely formed through wave erosion especially when the weakness is initiated by wave abrasion and hydraulic action. A typical example can be found in Senya Beraku near Winneba in Ghana, West Africa and Flamborough Head in England.

An arch is an opening through a mass of rock. It may be circular or cylindrical in shape and has steep-sided internal slopes. It is formed on a coast where waves constantly erode a hole through the weaker rocks of a projecting rock outcrop. It may be found also in places where two caves approaches each other from either side of a headland or a highland coast. Examples can be found in the Needles Eye near Wick in Scotland. An arch is steep-sided and rising high above the sea. An arch may eventually collapse when wave erosion is further intensified.

A stack is a steep pillar of rock rising from the sea and is formerly part of the mainland that has become isolated due to persistent wave action. The erosion is usually begun along a fault-line on a headland or cliff. Constant

attacks from both sides of the headland often result in the collapse of the arch roof which will later form an arch and a natural bridge. A fine example of an arch is the Old Man of Hoy which is found in the Orkneys in United Kingdom. It is an Old Red Sandstone that is about 135 metres high.

A stump is a remain of a collapsed stack. They are formed when the vertical pillars of a stack are further eroded. The erosion of the vertical rock pillars will leave behind these stumps that are only visible above the sea level. Examples include those of the St. Kilda group, off the coast of Hebrides, in Scotland, United Kingdom. They are also found along the coastlines of Senegal and Ghana in West Africa.

4. Geos and Gloups

Gloups are formed out of the occasional splashing of sea waves against the roof of a cave. This may enlarge the joints of the rocks when compressed air is trapped inside. As a result of this, a natural shaft is formed which may eventually pierce through to the surface. A gloup is otherwise known as a BLOW HOLE. The collapse of the roof of the cave leads to the formation of a gloup. An example is at Holborn Head in Caithness, Scotland.

A geo is an elongated narrow inlet with vertical sides leading inland from a sea-cliff. A consistent and vigorous erosion along the foot of a cliff through a line of weakness such as a joint or fault will later result in the formation of a cave which progresses inland as the erosion continues. A ready example of a geo can be found in the Old Red Sandstone Cliffs in Northern Scotland and the Wife Geo near Duncans by Head in Scotland.

Fig. 5.4: Geos and Gloups

5. Overhang and Undercut

These are remains of a cliff after a prolonged action of wave erosion. An undercut results when the base of a cliff has been seriously eroded. An overhang is the surface of a cliff that is left standing after a long process of wave erosion.

5.5 Landform Features Produced by Wave Deposition

There are several landform features produced by wave deposition but the major ones include:

(i) Beaches
(ii) Spits and Bars
(iii) Marine dunes and Belts
(iv) Mudflats

(i) Beaches: These are areas of sloping ground found along a coast. They are often found between the highest high-water mark and the

lowest low-water mark. Beaches consist of materials such as shingle, pebble and sand. Beaches that consist mainly of stones are called shingle beaches, while those made up of pebbles are called pebble beaches and those made up of sand are called sand beaches. Beaches are found along a greater part of the West African coast e.g. Lagos, Badagry, Accra, etc.

Waves generally produce depositional features through the process of longshore drift which rolls to the shore at the rate of 6-8 per minute. These waves are highly powerful and they are capable of moving materials such as shingle, sand and pebbles all of which are deposited along shoreline to form extensive beaches. In the process of forming beaches, backwash is weak and as a result is incapable of carrying the heavier materials which had been carried earlier by the swash and deposited at the top of the beach or back into the sea. Hence, it is clear that the backwash can only remove finer materials such as sand or silt because of their weight down the sea along the bed, and from there deposit them on the off-shore terrace and even beyond. Beaches are gentle platforms formed from the main action of constructive waves which involves the deposition of pebbles, sand and mud on a long stretch of land. The materials are transported along the coast by longshore cliff. Beaches are usually found between high and low water levels but through the storm waves, pebbles and stones are thrown well beyond the normal level reached by waves at high tide. The persistent deposition of materials in this manner results in the formation of level platforms known as storm beaches which has the shape of a large ridge.

In most bays, wave action is not strong and as a result deposition is the most dominant activity. This activity often leads to the formation of bay beaches and they are normally found at the head of bays. These beaches do not extend to the headlands where wave erosion is dominant. Examples include bay beaches that occur along the east coast and west coast of Malaysia. It should be noted that the constant wave action automatically causes the various shoreline deposits to be sorted out in a graded manner. The coarse or rough materials are dropped by the waves at the top of the beach. The finer materials are carried along down the beach as backwash and dropped closer to the sea.

Characteristics of Beaches

(i) A beach is a feature of coastal deposition.

(ii) It is gently sloping with the landward side backed by sand dune, succeeded by areas of sand and rocks covered with weed at or about low tide mark.

(iii) Sometimes, beaches may be covered by sea water at low tide.

(iv) The coarse material occurs at the top of the beach while the fine materials are found close to the sea.

Fig. 5.5: A Beach

2. **Spits:** This is a low, narrow ridge of pebbles or sand joined to the land at one end with the other end terminating in the sea. A spit may sometimes develop at a headland and project across a bay. As waves swing into the bay obliquely, the end of the spit becomes curved or hooked. They are elongated or curved depending on the extent of deposition of sand dunes. Spits may curve or have a hook or be straight as sediments are being deposited constantly. Spits are common along the coast of Senegal and Liberia.

Fig. 5.6: Spits

3. **Bars:** This is a bank of mud, sand and shingle deposited in water offshore parallel to the coast. It may be deposited across the mouth of a river, across the exit of a harbour, across a bay, between two headlands or between an island and the mainland e.g. a Tombolo. They are built on the sea floor by waves and currents. There are several types of bars depending on their positions. A harbour bar is found at the mouth, an off-shore bar which is found parallel to the coast, while a bay-bar connects two promontories across a bay, a tombolo is a bar which joins two islands. Bars are products of tidal seas and occur at the break-point of waves. Bar consists of ridges of shingle and sand projecting above the sea at a little distance off the shore. Bars are very similar to ridges. An example of a bay-bar is the Nehrungs that are found along the coast of Poland. A tombolo can be found along the Chesil Beach in Southern England while off-shore

bars are found in the southern part of the Atlantic Coast of North America.

4. **Mudflats:** This is formed from the deposition of fine silts and sand along gently shelving coasts especially in bays and estuaries. The deposition of these silts coupled with the dropping of alluvium by rivers joining through estuaries results in the building of a platform of mud called Mud Flats. After some time, salt tolerant plants begin to grow on the top of the mudflats which will later form a marshland and in tropical areas become mangrove swamps.

5. **Marine dunes and belts:** These are masses of fine sand particles which result from the effect of the off-shore winds. They are carried landwards by these winds and have been caused by onshore wind deposition. These sand dunes form extensive marine dunes that can eventually stretch into dune belts. These dunes can cover several villages spread over long distances. Examples include the dunes of Landes, South-West France and along the coasts of Belgium, Denmark and the Netherlands. To arrest the spread of these dunes and their destructive effects, shelter belts with sand-binding species of marram grasses and pines are grown.

5.6 Types of Coasts

A coast is an area bordering or close to the sea or ocean. It is a zone of contact between land and the sea. There are basically two types of coasts namely:

(a) Coastline of Submergence
(b) Coastline of Emergence

Coastline of Submergence

These are coasts that are formed due to a rise in the level of sea water and sinking of the land and as a result they become submerged. These coasts consists of:

(a) Highland coasts

(b) Lowland coasts

Submerged Highland Coasts

There are three main types under this category and these include:

1. Ria Coast
2. Longitudinal Coast
3. Fiord Coast

1. **Ria Coast:** This is a funnel-shaped coastal indentation formed by submergence due to rise in sea level affecting an area where hills and valleys meet the coasts at right angles. Due to submergence, the lower parts of the river valleys become flooded. This causes long narrow branching of inlets, separated by narrow headlands to be formed. Ria coasts can be found in Southwest Ireland, Southwest England, Northwest Spain and Britain. They are also found along the coast of West Africa especially Gambia and southern Sierra Leone.

Characteristics of Ria Coast

(i) They are long and narrow with inlets separated by headlands.

(ii) They are backed by highlands.

(iii) They decrease in width and depth inland.

(iv) They support few large commercial ports though they have deep water and also offer sheltered anchorage.

(v) They are usually sites for fishing ports and narval bases such as Plymouth (UK) and Brest (France). Freetown which is a natural harbor in West Africa is founded on a ria coast.

Fig. 5.7: Ria Coasts

2. **Fiord Coast:** These are submerged U-shaped valleys formed out of glacial action. They mark the paths of glaciers which has plunged down from the highlands. During glaciations, the river valleys become widened and deepened. After the glaciers have disappeared and the sea has risen, the steep-sided valleys become drowned. The water insider fiords are much deeper than it is at the entrance of the fiord. Fiords have steeper sides and deeper water than rias. All fiord coasts usually lie along the belt of prevailing westerly winds and are on the western sides of land masses. Examples of fiord coast can be found in Chile, South Island of New Zealand, Greenland, Norway and British Columbia. Fiords have steep walls often rising straight from the sea with tributary branches joining the main inlet at right angles. Due to intense ice erosion, fiords by nature are deep for

great distances inland but there is a shallow section at the seaward end formed by a ridge of rock called the *threshold*.

Fig. 5.8: Fiord Coasts

Characteristics of Fiord Coast

(i) They have the same characteristics of a glaciated U-shaped valley.

(ii) They are U-shaped with hanging valleys and truncated spurs.

(iii) They have steep-sided slopes.

(iv) They are long, narrow and rectilinear with numerous branches joining at or near right angles and are common along the western coasts of Norway.

(v) In spite of their deep and sheltered water, few large ports are located in fiords.

(vi) Their mountainous background coupled with poor accessibility inland makes them unattractive as settlement sites and indeed important activities such as agriculture.

3. **Longitudinal or Dalmatian Coasts:** These are coasts found in areas where mountains run parallel or concordant to the coast. The name of this coast originates from the coast of Damatia in former Yugoslavia, along the Adriatic Sea, where the submergence of the coastline

produces long, narrow inlets with a chain of inlet parallel to the coasts. The separating mountain ranges later become islands while the valleys are called *sounds*. They are common in USA, Yugoslavia and along parts of the Pacific Coasts of North and South America.

Characteristics of Longitudinal Coasts

(i) They are formed when a highland coastal area is submerged.
(ii) They tend to be straight and regular.
(iii) The outer ranges become longitudinal line of islands and the parallel valleys form long grounds.
(iv) Due to their mountainous nature, their coastline hinders communication inland and has few ports despite its sheltered harbours.

4. **Estuarine Coast:** This is a typical example of a submerged lowland coast. This coast are found in submerged lowlands where the mouth of rivers are drowned so that funnel-shaped estuaries are formed. Often times, a rise in sea level along a lowland coast causes the sea to penetrate inland along the river valleys often to considerable distance. On most estuarine coasts, marches, swamps and mudflats are often seen usually at low tides. Examples of this coast can be found in the Baltic coasts of Poland and Germany and the Dutch coast.

Coastline of Emergence

These coasts are formed as a result of the uplift of the land or a fall in the sea level. They are less common and are represented by the uplift lowland coast and the emergent upland coast. They consist of:

1. Uplifted lowland coast
2. Emerged upland coast

1. **Uplifted Lowland Coasts:** These are coasts which result from the rise of an upland area along the coast. They are formed when a highland coastal area is raised as a result of faulting and earth movement.

Characteristics of Uplifted Lowland Coasts

(i) They are raised beaches which are beyond the reach of waves.
(ii) The beaches are found along the lines of cliffs.
(iii) They sometimes possess arches, stacks and other coastal features.
(iv) The coasts are straight with steep cliffs and deep off-shore waters.

Examples can be found in Scotland, Western Coast of India and Coasts of Mexico.

Fig. 5.9: Uplifted Lowland Coasts

2. **Emerged Lowland Coasts:** These are lowland coasts formed when a part of the continental shelf emerges from the sea and for a coastal

plane. The coasts have no bays or headlands and deposition takes place in the shallow waters offshore.

Characteristics of Emerged Lowland Coasts

(i) The coasts are smooth and gentle sloping.

(ii) The offshore waters along the coasts are shallow with lagoons, salt marshes and mudflats.

(iii) Where the emergent deposit from the continental shelves are sandy and gravelly, beaches and marine dunes are formed.

Examples of emerged lowland coasts include the Southeast USA, Western Finland and Eastern Sweden.

Summary

- Waves constitute one of the active and dynamic agents that wears and shapes the surface of the earth especially along the coasts.
- Waves, ocean currents and tides play important role in the creation and modification of coastal landforms in all parts of the world.
- The effectiveness of wave action on coastal areas is determined by the interplay of some factors such as wave energy, the nature of coastal rock outcrops and surface, exposure of the coast to erosional activities.
- The processes of wave action include hydraulic action, corrosion or abrasion, attrition or corrosion and solution.
- Wave action involves three activities: erosion, transportation and deposition.
- Wave erosion produces landform features such as cliffs, promontories, stacks, arches, geos, blowholes, caves etc.

- Wave deposition results in the formation of landform features such as spits, bars, beaches, mud flats, marine dunes etc.
- Wave action also results in the formation of coasts and they can be grouped into submerged coasts and emerged coasts.
- Coasts serve several purposes to man such as settlement sites, natural harbour for ports, source of minerals, tourist attractions, etc.

Objective Questions

1. A sand spit is
   A. a sand bank running into the sea or lake.
   B. a high sandy cliff.
   C. an area of desert.
   D. a deposit of sand in a quarry.
2. Where a spit cuts off or nearly cuts off an area of water from the sea, the feature formed is
   A. a lake. B. a delta. C. a sea-stack. D. a lagoon.
3. In which of these areas would you find fiords?
   A. southern Chile B. South-Western Ireland C. Norway D. Alaska
4. A piece of land cutting out into the sea is
   A. a bay B. a cliff C. an isthmus D. a cape
5. Which of these capes is not in Africa?
   A. Cape Verde B. Cape Cod C. Cape Agulhas D. Cape Palmas
6. The most important agent that modifies a coastline is
   A. waves B. wind C. tides D. ocean currents
7. Which of the following is not a depositional shoreline feature?
   A. Spit B. Arch C. Tombolo D. Salt march
8. Areas of water trapped behind bars are sometimes called
   A. lagoons. B. salt lakes. C. estuaries. D. reservoirs.

9. Which of the following is not associated with waves?
   A. Fletch B. Plunge C. Swash D. Drift
10. Which is the odd one out?
   A. Stack B. Wave-cut bench C. Spit D. Cave

Essay Questions

1a. Distinguish between hydraulic action and abrasion as processes of wave action.

b. With the aid of suitable diagrams, describe the formation of the following:
(i) Wave-cut platform (ii) cliffs (iii) bars (iv) beach

2a. Differentiate between constructive waves and destructive waves.

b. With the aid of suitable diagrams, describe the characteristics and mode of formation of: (i) spit (ii) arch (iii) caves (iv) headland

3a. Distinguish between waves and tides.

b. With the aid of suitable diagrams, describe the formation and appearance of the following features: (i) stack (ii) arch (iii) bars (iv) mudflats

4a. Describe the characteristics of a ria coast.

b. Suggest five importance of coasts to man.

5a. Describe the main destructive and constructive processes at work along coasts.

b. Suggest four characteristics of fiord coasts.