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Component I(B) Description of Module

1	**Items**	**Description of Module**
2	Subject Name	Geography
3	Paper Name	Geomorphology
4	Module Name/Title	Coastal processes and Landforms
5	Module Id	GEO/25
6	Pre-requisites	
7	Objectives	To understand the coastal processes that shape the landscape near the sea. Understand the importance of waves, tides and winds, landforms of coastal erosion, landforms of coastal deposition
8	Keywords	Fetch, surf, breaker, longshore current, rip current, beach,

COASTAL PROCESSES AND LANDFORMS

Introduction

The landscape is sculptured by the various processes operating on the surface of the earth. Mass wasting, erosion by wind, rivers, underground water, glaciers all contribute to shape and modify the landscape. In this Chapter we understand the coastal processes that are shaping the landscape and see how the waves through the process of erosion, transportation and deposition of detrital material continues to bring changes in the shorelines of the earth. Waves transfer the energy they derive from wind to shoreline that in turn is used to erode, move sediments and deposit them forming various coastal features. The other processes that work in the coastal waters include wind, tides and currents which along with waves provide the requisite energy to carve out and modify the physical features.

Waves

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Waves are undulations over water surface resulting due to action of wind. As the wind blows over water, it produces stress and pressure variations on the surface, resulting in generation of waves that grow as result of pressure contrast between their driven (upwind) and advancing (downwind) slopes. The height of waves and their length and speed are controlled by the wind speed, the length of time the wind blows and distance the wind blows over water (*fetch)*. The largest waves form where high winds blow over a large expanse of open water for an extended period of time. (Plummer and Carlson, 2007). Waves consist of orbital movements of water that diminish rapidly from surface downwards, until motion is very slight where the water depth (*d)* equals half the wavelength (L). The depth at which waves become imperceptible is termed the wave base (Bird, 2008). Orbital motion is not quite complete so that water particles move forward as each wave passes, producing a slight drift of water in direction of wave advance. A particle of water moves in an *orbit* almost in a circular path. The particle returns to its original position after wave has passed. In deep water, when wave moves across water surface, energy moves with wave but the water does not move with wave and advances in circular orbits.

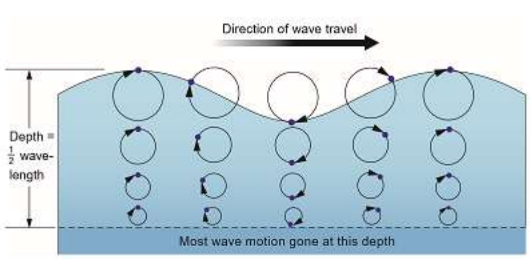
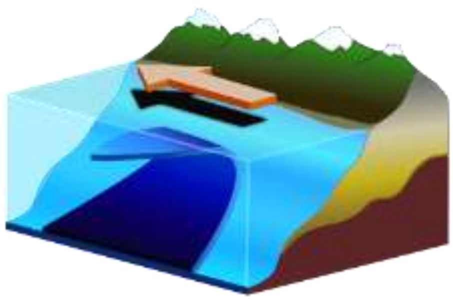


Figure 1: Orbital motion of water particles in a wave
Source: Adapted from Plummer C.C and Carlson D.H (2007). Physical Geology

Wave height is the vertical distance between **crest** – high point of wave and **trough** – low point of wave. Wave steepness is the ratio between the height of wave and the length, while wave velocity is the rate of movement of wave crest. In open ocean waves have height between 0.3 to 5 metres, but large storm waves generated by strong winds may reach upto a height of 20 metres, particularly during times of hurricanes and cyclonic storms. Waves break against the shore as **surf** when a large portion of their energy is expended in moving sand along beach. Waves move from deep water to shallow water near shore during which they are influenced by the ocean bottom. At the level of lowest orbital motion, when depth to bottom is equal to half wave length (Figure 1), the wave will begin to feel the bottom. A wave 100 metres long will begin to be influenced by bottom at water depth of 50 metres. In shallow waters, the completely circular orbits flatten into ovals, slowing down the waves, but increasing wave height as it encounters the sloping bottom wedges. The height continues to increase and simultaneously length decreases, waves become steeper and steeper and finally break. The **breaker** is steep wave whose crest topples forward, moving faster than main body of water. Collectively the breakers are termed as **surf.**



https://en.wikipedia.org/wiki/File:Upwelling.svg

The wave moves towards the coast and crashes against the solid land surface or built up structure. Sometimes it crashes with a high impact, disintegrating the rocks or any other structure. At times the waves break before reaching the coast and the water surges forward forming what is known as **swash.** As the water moves forward as swash it carries with it the small detrital material and fine sand particles carrying them to beach. The water then retreats back due to gravity and drains back towards the sea as **backwash.** In this process the water transports some of the sand from the beach back in sea. The process continues and with each **swash** and **backwash** sand material is continuously being flung on shore and then returning back to sea.

Near Shore Circulation

Wave Refraction

The sea waves generally do not strike the coast in a straight line. As the waves approach the shore, they bend, that is, first to arrive on the shore is the wave crest at an angle to shore. In this process one end of wave breaks first that is followed by rest of wave progressively breaking along the shore. This angled strike of wave changes the direction of wave travel. As one end of wave reaches shallow water it 'feel' the bottom and slows down, while the rest of wave travels at the same deepwater speed. More and more waves come in contact with bottom, continuously slowing the speed of wave. The speed of wave slows progressively along its length. This way there is change in direction of wave crest till it becomes almost parallel to coast. This process of bending of waves as they enter shallow water is termed as **wave refraction.** The wave refraction occurs in both straight shorelines and irregular shorelines of headlands and bays. Due to refraction wave energy is concentrated along certain parts of shoreline and may be low in others. This further has consequence on the erosional ability of the waves.

Longshore Currents

Within the surf zone, the movement of water is almost parallel to the coast, creating longshore current. These are generated by the waves entering the surf zone at an oblique angle. After wave refraction, wave crest and shoreline have a slight angle between them. Due to this the water is driven up the beach towards land and along beach parallel to shoreline (Strahler,2011). With each wave striking the shore at an angle, more water is pushed parallel to shore. Longshore current have about the same width as that of surf zone, wherein the landward end is the shoreline and the seaward edge is the outer limit of surf zone where the waves are just beginning to break. If the wave size is large the longshore currents tend to be strong and powerful and depending on the angle of wave approach and incident wave energy level, their velocity may exceed more than 1 metre per second (Holden, 2018).The longshore currents can carry suspended sediments along the beach over long distances.

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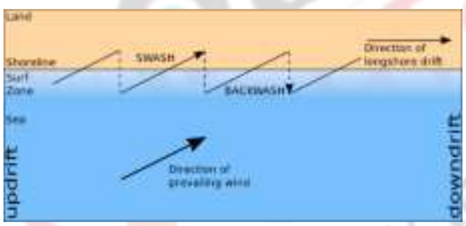

https://commons.wikimedia.org/wiki/File:Longshore_drift.svg

Rip Currents

Rip currents are narrow channels of strong seaward moving currents that occur near the shore through surf zone. These currents travel at water surface and with increase in depth they dissipate and die down. Their presence can be seen as stripes of frothy and turbid water that flows perpendicular to shore. The velocity of rip current varies between 0.5 – 1 metre per second, being highest during high tide (Holden, 2008). The currents exhibit pulsating characteristics attaining greatest speed when large waves with high amount of water is carried on to shore. They transport large amounts of fine-grained sediments from the surf zone into sea.

http://www.noaanews.noaa.gov/stories2007/images/desgrip01.jpg

Rip Current, N.Carolina Coast.
Source: NOAA Oceans Today

Tides

The movement of ocean water due to the gravitational attraction of moon and sun in relation to earth is termed as **tides.** These are long waves travelling across oceans and transmitted into inlets, bays, lagoons or estuaries around the worlds coastline. The ebb and flow of tides produces changes in sea level at regular intervals and generate **tidal currents.** These currents may flow at speed of 3km/hour in open oceans and may exceed 20 km/hour where the flow is channeled through gulfs, straits between islands and entrances to estuaries and lagoons. Tidal oscillations invading coastlines may set up longshore currents., for example on Norfolk coast in England, when 2-3hours before high tide the long shore flow is west ward and as the ebb sets in the longshore flow becomes eastwards (Bird, 2008). The tidal currents have a little impact on erosion or deposition, they rather act as transporting agents, carrying sediments along coast in nearshore zone.

Winds

The action of wind in shaping and modifying structures along the coast are also visible. Strong winds are known to deflate fine-grained sediment from beaches and tidal flats, lower their surface and causes movements of detrital material and rock particles onshore, alongshore and offshore. Dunes are formed above the high tide level by deposition of sand blown from beach. The wind also aids in transport of fine sediments that have resulted from weathering on shores due to process of wetting and drying by waves or tides and salt crystallization. The wind blown particles may act as abrasive tools as they bounce and roll down the rock surfaces on the shore. These rocks are scoured or rounded and smoothened by these sand particles. Evaporation and drying out of wet outcrops on cliff faces and wave cut platforms is enhanced by the wind (Strahler,2011).

Coastal Erosion

As already discussed above, waves, currents, tides and wind play a significant role in marine erosion. However, there are other controlling factors that influence the rate of erosion in coastal areas (Thornbury, 1997). These are a) Kind and durability of rocks along shore b) Structural controls such as fractures and joints c) Tidal range d) Openness of shore to wave attack e) Depth of water offshore f) Configuration of coastline g) Presence or absence of protective beach h) Abundance and size of abrasive toolsi) Stability of sea level

Five major processes that contribute to coastal erosion are **corrosion, corrosion or abrasion, attrition, hydraulic action and shock pressure of breaking waves.**

Erosional Coastal Landforms

Erosive action of waves, winds and currents on the coasts form distinctive topographical features. In the following section we discuss the landforms made by erosive action.

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Cliff

The seaward limit of coast in some places is marked by a nick or scarp commonly known as **cliff.** Cliffs are steep, (with angles of more than 40º, sometimes even vertical and sometimes hanging), coastal slopes cut into rock formations (Bird, 2007). The subaerial erosion of the cliff face and wave erosion at the cliff base recedes the cliff backwards. In the coastline of the world, more than three quarters are rocky and cliff faced. Formation of cliff is strongly influenced by the geological structure of the coast and its response to weathering. In areas of resistant rocks, the cliffs are often vertical or steep. In areas where less resistant formations are cut back as cliffs, there is presence of irregular rocky shores or smooth shore platforms that are exposed at low tide.

http://learning.uonbi.ac.ke/courses/SGP323/scormPackages/path_2/93_wave_action.html

Coastal East Lothian : Wave-cut Platform and Cliffs, Dunbar

Source: http://www.geograph.org.uk/photo/3436717

Wave cut platform

Wave-cut platforms or Shore platforms border many cliffs and extend across the intertidal zone. Whereas the term wave cut platform is mainly restricted to geomorphic features shaped entirely by hydraulic action of waves on soft rocks such as clay shore platforms are formed due to abrasion by waves containing sand or gravel, tidal scour and weathering. Presence of a shore platform reflects the stability of the coast over a long period of time maintaining the same level of sea. In case of change in sea level, one can observe the presence of **marine terraces** that are elevated wave cut benches marking former high sea level (Thornbury,1997).

Caves

As the cliff recedes coastal erosional processes of weathering and erosion penetrate zone of weakness such as faults, joints or outcrops of less resistant rocks. These processes cut clefts and crevices that further develop into caves and blow holes or deep, narrow inlets with stacks. Marine erosion thus has acted on the zones of weakness or segments of weaker rocks in Scotties island of Staffa Fingal's Cave is 20 metres high and 70 metres ling in columns of tertiary basalt. In southern Corsica caves of Bonifacio on the limestone coast have originated as subterranean solution caverns.

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Blowholes

The Blowholes develop in a cave when the hydraulic action of incoming waves and the compression of trapped air punctures the roof of the caved with the water and spray driven up through it as fountains of spray. Kiama in New South Wales and Quobba in Australia are examples of blow holes occurring in elongated cave cut along joints in basalt. Blowholes formed in layered carboniferous sandstone in Mayo in Northwest Ireland are known as puffing holes.

Natural Arches

Natural Arch is formed when powerful wave action excavates cave along joints and weak fractures on a cliffed coast on a headland. The wave action cuts through the caves on both sides of the headland producing this spectacular geomorphic feature. On the Normandy coast of France Porte d' Aval is a natural arch on cliff of Heartchalk. Sometimes elongated natural arches may form tunnels. One such example is the tunnel on the north coast of Cornwall Merlin's Cave (Bird,2008).

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Stacks

Dissection of headlands on a cliffed coast often isolate stacks either when a natural arch collapses or when a transverse inlet is cut along a zone of weakness through the headland. Finally they may be reduced by erosion and continue to be undercut till they collapse leaving only a basement platform. Examples are Twelve Apostles near Port Campbell Australia.(Bird, 2008)

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TOPOGRAPHIC FEATURES RESULTING FROM COASTAL DEPOSITION

Beaches

Beach is an accumulation of loose unconsolidated sediment, temporary veneer of rock debris ranging in size from very fine sand, to pebbles, cobbles and occasionally boulders. Nearly about 40 percent of the coastline of the world consist of unconsolidated deposits of sand and gravel. The beaches may extend for several kilometres or may be patchy. They may be almost straight or gently curved; some may be short and include sharp curved pocket beaches in bays or coves between rocky headlands. Some are exposed to open seas and some are sheltered in bays. The movement of sediments of sand and other particles by waves and currents from one sector to another, changes the shape of the beach. The movement of longshore current and longshore drift, when waves arrive at an angle to the shore changes the beach morphololgy and when the sediments are moved to and fro between the beach and nearshore zone as waves break parallel to the coastline also helps in shaping the beach.The beach accretion mainly takes place during periods of relatively quiet seas and beach thickness is most significantly altered during storms. In coasts with high wave energy, large particles can be moves and beaches tend to be steep relative to coastal areas where low wave energy defines presence of only fine material. In the dynamic coastal system, the beach reflects an equilibrium state between input of material by swash and removal by backwash (Holden, 2008). The underlying structural rock formations of Granite, basalt, shale, conglomerate, and coral define the type, colour and texture of various beaches.

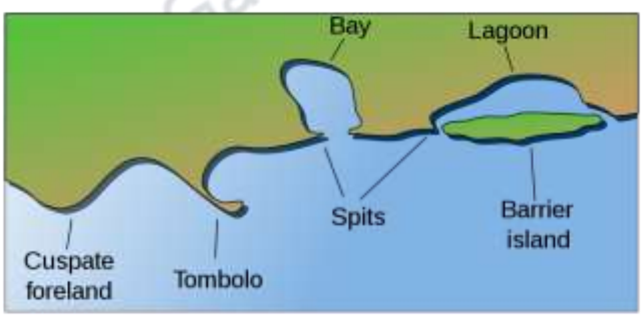
A prograding beach shows net accretion, receives more sediments from different sources than losing it on shore, offshore or alongshore. The transverse profile of a prograding beach is convex or in form of a terrace ending in an seaward slope. Longshore drifting of sand and shingle may lead to some beaches to prograde. For example., Cardigan bay on west coast of Wales, Streaky bay, South Australia and Danish Island of Kyholm.

Spits

The spits are beaches that are built above high tide level, diverging from the coast, ending in one or more landward hooks or recurves (Schwartz, 1972). The outlines of the spits are shaped by the dominant pattern of wave action, and they grow in direction of longshore drift by waves arriving at an oblique angle to the shore. Example of straight longshore spit is Orfordness, East coast of England and recurved spit is seen at Hurst Castle, Hampshire (Bird, 2008). Evans (1942) defines it as ridge or embankment of sediment attached to land at one end and terminating in open water at the other. The axis of **spit** usually extends in a straight line parallel to the coast, but, when currents are deflected landward or tides are strong, growth of a spit may deflected landward, with the resulting creation of a **recurved spit or hook.** Several stages of hook development may produce a **compound recurved spit or compound hook.** Spit may be attached at both ends to headland to form **winged headland.**(Thornbury, 1997)

If two spits converge offshore or a simple or compound spit recurves until it becomes attached to shore at both ends, a **cuspate spit** is formed**.** Growth of successive cuspate spit farther and farther seaward will cause prograding of the shoreline and seaward extension thus formed is known as a **cuspate foreland. Examples – Cape Henry, Virginia and Cape Kennedy (Canaveral), Florida.** (Thornbury, 1997)

https://commons.wikimedia.org/wiki/File:Barafundle_Bay_beach_(May_2009).jpg



https://commons.wikimedia.org/wiki/File:Accreting_coast_Image6.svg

Bars

The term **bar** in generic sense includes various types of submerged or emerged embankments of sand and gravel built on sea floor by waves and currents. They may be emergent at low tides. They extend parallel to the coastline. Between a bar and a coastline and between nearshore bar, there are elongated troughs where the water is deeper. Bars may be exposed at low tide and submerge during high tide creating intervening troughs that contain lagoons as the tide falls. Most bars are sandy with pebbles and shells. Migrating bars become asymmetricalwith steep advancing slopes. During calm weather and quiet seas with effective constructive swash, bars move closer to the shore and depict a flat profile.

Barrier beaches and barrier chains.

Barrier beaches consist of elongated landforms and sand ridges parallel to the shore, which rise slightly above high tide. They are formed by the deposition of beach material offshore or across the mouths of inlets or embayments. In case of gently sloping coasts, waves may break at a considerable distance from the shore, thereby enabling churning waters to build submerged offshore bars running parallel to the coast. These bars gradually grow and emerge above sea level and stand as a barrier between the open sea and an earlier coastline and often result in coastal progradation. In due course of time, they form barrier beaches and possibly large barrier islands. There are three distinct zones of the barrier island – a sandy beach; a sand dune and a shallow lagoon or swamp between barrier island and mainland. A series of these features extending for a considerable distance is known as **barrier chain.** In the low relief coastlines, barrier islands are the most common features, dominating Atlantic and Gulf coasts from New York to Texas; ocean coasts of South Africa and Eastern South America.